YOUR FIRST ATARI® PROGRAM

Rodnay Zaks

SYBEX

"Yes . . . YOU can!"

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YOUR FIRST ATARI PROGRAM

YOUR

PRO

FIRST ATARI® GRAM

Rodnay Zaks

Illustrated by Daniel Le Noury

SYBEX®

Berkeley • Paris • Düsseldorf

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1 Speaking BASIC

Introduction 1

Programming 2

The BASIC Interpreter 4

What is BASIC? 6

Which BASIC? 7

Your Computer 8

Computers and Syntax 13

2 Communicating with Your Computer

Introduction 14

Using the Keyboard 16

Speaking BASIC 20

A Longer Program 28

Summary 33

Exercises 34

3 Calculating with BASIC

Introduction 36

Printing Numbers 38

Scientific Notation 39

Doing Arithmetic 40

Printing Formats 43

Application Examples 45

Summary 46

Exercises 46

4 Memorizing Values and Using Variables

Introduction 49

The INPUT Statement 50

The Two Types of Variables 53

Assigning a Value to a Variable 60

The Variable Counter Technique 65

Summary 66

Exercises 67

5 Writing A Clear Program

Introduction 68

The REM Statement 70

Multiple Statements on a Line 71

Using Blanks 72

Improving the Display 74

Shortcut Input 74

Selecting Variable Names 76

Proper Line Numbering 76

Summary 79

Exercises 79

6 Making Decisions

Introduction 81

The IF Statement 82

An Arithmetic Drill 90

The GOTO Statement 94

IF Statement Revisited 96

Counting Ones 97

Arithmetic Drill Revisited 99

Validating the Inputs 99

Mileage Conversion 100

Birthday 101

Summary 102

Exercises 102

7 Automating Repetitions

Introduction 104

The IF/GOTO Technique 106

The FOR . . . NEXT Statement 109

Sum of the First N Integers 111

Tables of Values 112

Lines of Stars 113

Advanced Looping 114

Additional Features 118

Summary 119

Exercises 119

8 Creating a Program

Introduction 121

Algorithm Design 122

Flowcharting 126

Coding 134

Debugging 136

Documentation 138

Summary 140

Exercises 141

9 Case Study: Metric Conversion

Introduction 143

Designing the Algorithm 144

Flowcharting 144

Coding 151

Testing 158

Summary 160

Exercises 161

10 The Next Step

Introduction 163

What Can You Do With BASIC? 164

Improving Your Skills 164

More BASIC 165

Conclusion 169

Appendices

Answers to Selected Exercises 171

Atari BASIC Reserved Words 176

BASIC Glossary 177

Index 180

Preface

Hundreds, perhaps thousands, of books have been written about programming.

Why another one? Simply because the audience has changed. In the past, using programming languages such as BASIC was the privilege of the few who had access to computers. Programmers were a small elite group. This is no longer the case. The majority of computer users today have little or no technical background. They use computers for fun, education, business, or their profession.

This book addresses this new group of users. Not only does it *look* different, but it *is* different. It is intended for the beginner and thus assumes that the reader has no prior technical knowledge. Personal computers have made BASIC the most widely used and most accessible computer language ever. This book is for everyone—whether aged 8 or 88—who wants to learn quickly how to get started in BASIC with their Atari computer.

The author believes that all new computer users who want to learn how to write their own programs in BASIC are enthusiastic and young, or young-at-heart. They want a simple, straightforward, educational approach to learning BASIC. That is the approach of this book: It is designed to make learning to program in Atari BASIC easy and fun.

Furthermore, this book aims at teaching you the essentials of BASIC in just a few hours. You should be writing your first BASIC program within one hour. And within a few hours, you should know enough to start writing useful and meaningful programs.

Time is passing . . . let's begin.

The author wishes you a pleasant journey along the magical path to knowledge.

Rodnay Zaks
Berkeley, September 1983

How To Read This Book

This is an educational book. You should read every chapter in sequence and understand each one before you continue on to the next. I have provided exercises at the end of each chapter to help you test your new skills. Do as many of them as you can. Answers to selected exercises are provided in Appendix A at the end of this book.

If you have an Atari computer, try all the programs. To truly learn and remember, you must practice and experiment. This book will bring you the skills and knowledge you need to get started—but remember, nothing can substitute for experience.

The main goal of this book is to get you started programming your Atari in BASIC quickly and effectively. To achieve this goal and make your path simple, I have had to make choices; therefore this book does not describe every feature or concept of BASIC—just the important ones.

It is my hope that with this book you will understand everything quickly, and that in no time at all you will be writing your first BASIC programs, and appreciating and enjoying the power of your new programming skills.

What You Will Learn

Chapter One explains the language of computers and introduces you to the heroes of this book: the Computer, the Interpreter, the Program, the Instructions, and other characters of the cast.

Chapter Two shows you how to communicate with your computer, using the resources of the keyboard and the display. You will learn to type your first BASIC programs and execute them.

Chapter Three shows you how to perform calculations with BASIC.

Chapter Four helps you write programs that can be used repeatedly. In addition, you will learn how to use variables correctly and effectively.

Chapter Five shows you how to make your programs clear and readable.

Chapter Six shows you how to make complex decisions based on logic and values.

Chapter Seven explains how to automate repetitive tasks, using program loops.

Chapter Eight shows the correct method for designing a program from the algorithm to the working, documented program—including designing the flowchart.

Chapter Nine helps you apply all these concepts to a practical case study.

Chapter Ten helps you examine the next step to programming expertise.

The appendices A, B, and C offer answers to selected exercises, a list of common reserved words, and a glossary.

If you are ready, let's open up the family album and I'll introduce you to the heroes of this book . . .


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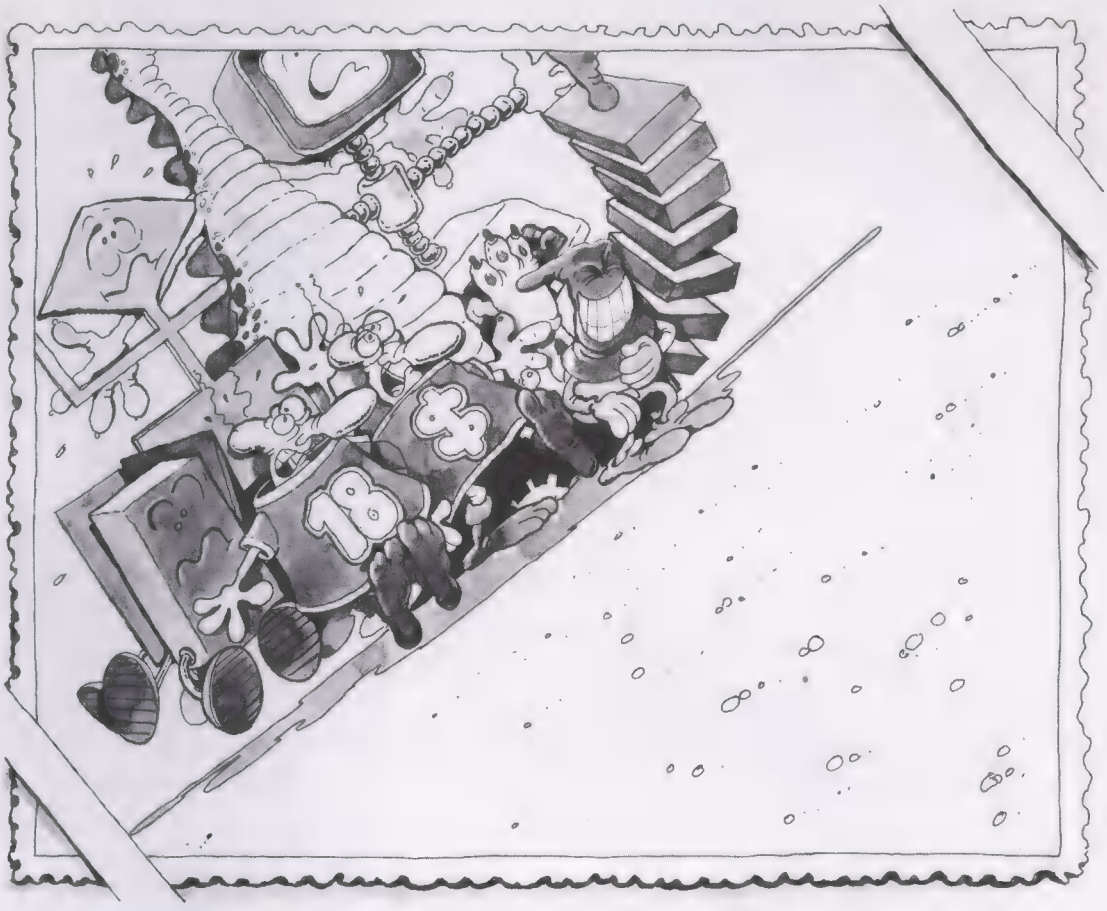
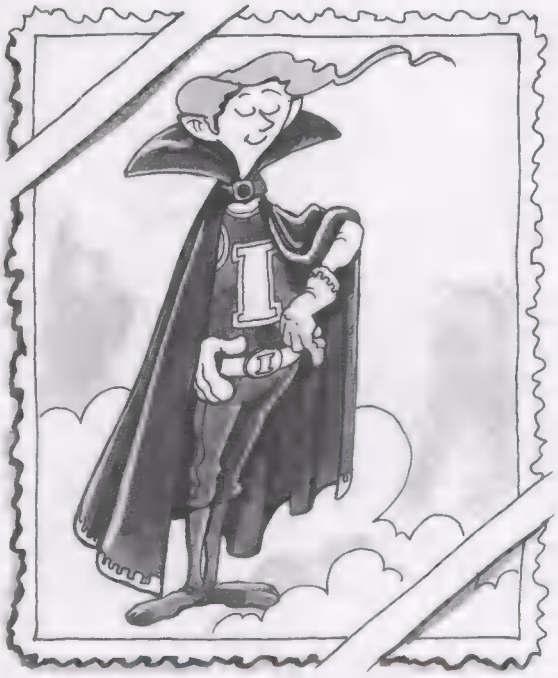
$

Meet Our Heroes

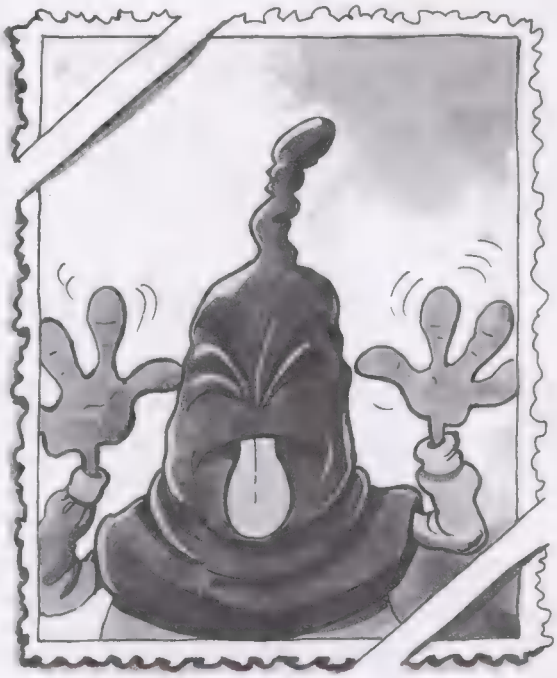
Featuring (going clockwise): Dino the Programmer, the BASIC Interpreter standing on his friend the Computer, the Program Snake, the mischievous Bug, two Variables, Program Instructions ready to walk to their assigned spot, and the indispensable flowchart on which Dino rests . . . Oops, our bug seems to be up to something!



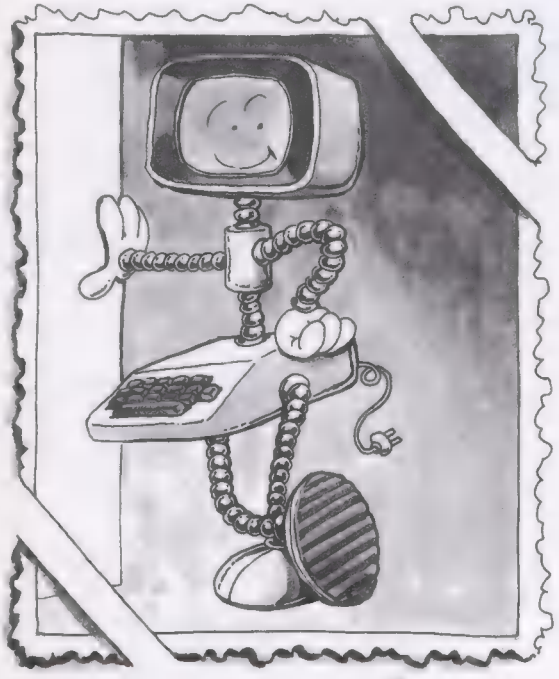
Sorry . . .
our mischievous
Bug did it again.
So much for
a group shot. . .



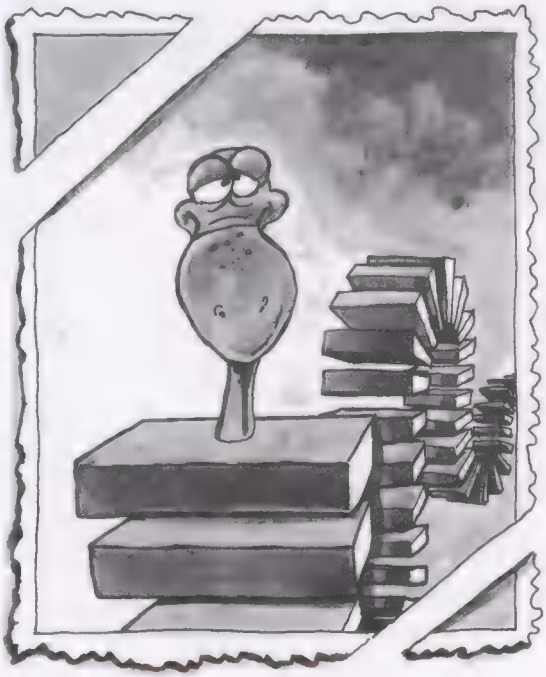
This is the BASIC Interpreter. When awake, he resides in your Computer's memory. His job is to translate your instructions to the computer. He will help you in any way he can.



Never forget this face. This is a Bug. He will make your life miserable. Do your utmost to keep him away from your programs.

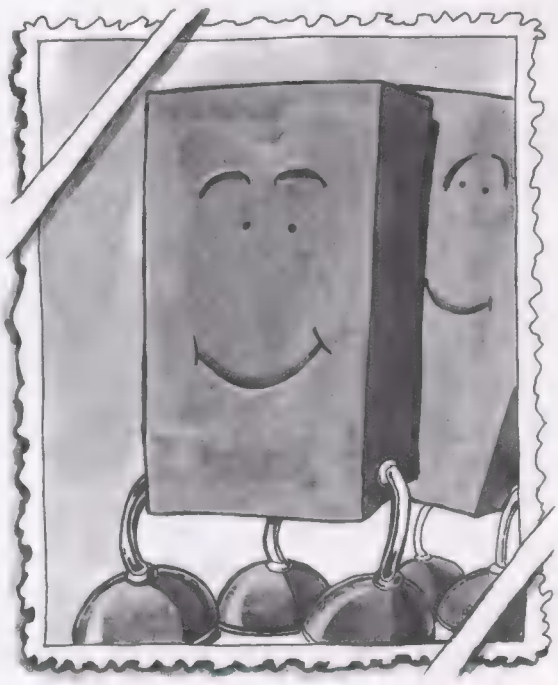


This is your friend the Computer—at your command.



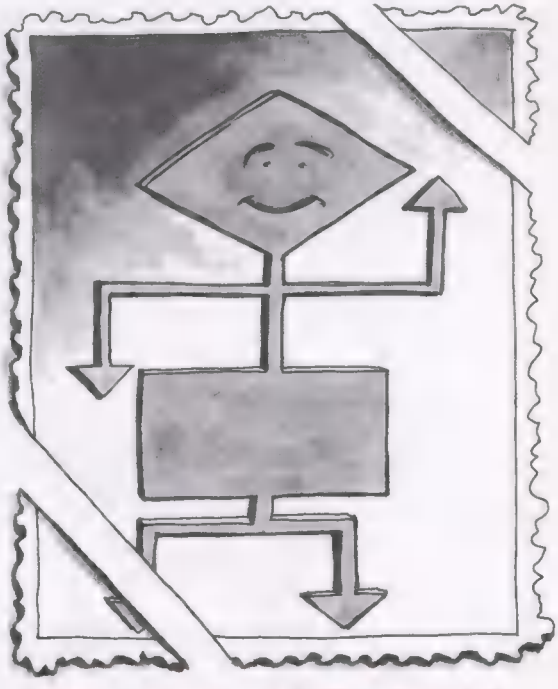
No, this is no monster—it's the Program Snake. He's made up of instructions. You'll learn to assemble him. He's very tame once you know him. Just keep Bugs away from him.

This is Dino. He's friendly and, although he has no formal education, he will show you how simple it is to write BASIC programs.



Here are the BASIC instructions, ready to join the Program Snake.

This is a numeric variable. His coat is labeled with his name, and he has a value imprinted on him. He's unhappy because he wants to go back to his reserved box in the memory.



This is your best friend, the Flowchart. He'll help you design programs that work.

Speakin

g BASIC

1

I claimed in the preface that "You will be writing BASIC programs within one hour."—so, why start with a chapter on concepts and definitions? Aren't we wasting time? On the contrary: Our purpose is to *learn* and *retain* information, and true learning requires depth of understanding. The information presented in this chapter will help you better understand what programming is, how a BASIC program is executed, and the vocabulary of computers.

Before we begin writing our first program, there are a few important definitions and concepts you should learn. Once you understand these terms, I can explain *what happens* and *what to do,* in a simple yet accurate manner, and you should be able to follow along easily. So read this chapter carefully to ensure that you truly understand what you are doing—and won't just be hitting keys.

We will begin by learning how to give instructions to a computer—this is called *programming.* Next, we will explain the need for *programming languages,* such as BASIC. Then we will discuss what a BASIC *interpreter* is, and we will explore the history of BASIC, its *dialects* and its uses. Finally, we will examine the components of a *computer system* and learn some of the technical jargon used to describe these components.

Programming

Your computer is a machine designed to process *information*—both textual and numerical. For example, you can make your computer display words and sentences on a screen—this is known as *text processing*—or you can make it convert a weight expressed in ounces into its value in grams—this is known as *numerical processing*. In order to make your computer perform this processing, it is necessary to issue instructions in a format or "language" it understands. Each computer can only "understand" (i.e., recognize and execute) a small number of different instructions (say, a few hundred).

Instructions that a computer can understand directly are called *machine language* instructions. These instructions are stored in *binary* format, i.e., in groups of 0's and 1's in the computer's memory. Each 0 or 1 is called a *bit*, and a group of eight bits is called a *byte*.

A sequence of instructions that accomplishes something useful is called a *program*. (A sequence of instructions that accomplishes nothing is an *error*.) Your computer executes a program by executing each instruction in turn. Unfortunately, writing a computer program (a sequence of instructions) in machine language, i.e., in binary form, is a slow and tedious process.

Ideally, we would like to be able to give spoken or written commands in everyday language (say, in English) to the computer and have it execute them. But, this is not possible since a computer cannot understand any of the usual languages—whether spoken or written. The reason for this is quite simple: A computer executes orders strictly and exactly; it is logical and precise; and it requires

Learn how to give instructions to your computer!

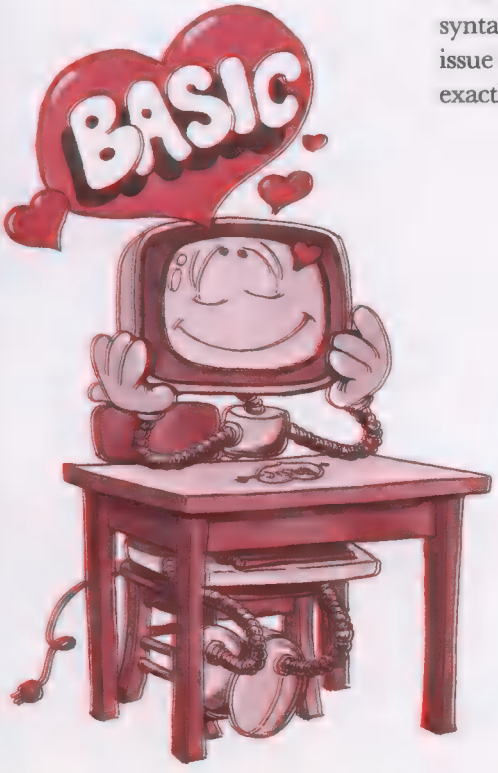
clear, unambiguous instructions in the proper sequence and form. The problem with a spoken language lies in the language itself—sentences can be ambiguous and often their meanings can depend on context, such as facial expressions or gestures. This type of communication cannot be interpreted by a computer.

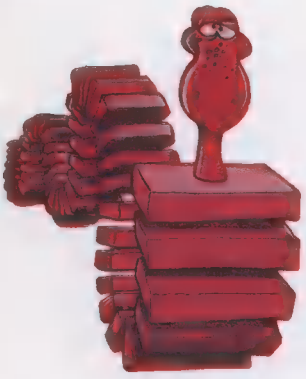
Even carefully written English remains insufficiently precise for a computer. For example, you cannot tell a computerized robot to "go to the kitchen and boil an egg," and expect results, unless the robot has been programmed to know its way around your kitchen. A robot has to be trained (or programmed) before it can operate in an environment like ours. And, even if a robot is trained to know its way around *your* kitchen, it may not be successful in a friend's kitchen, because things may be located in different places. Remember, communication with a computer must be clear, precise and unambiguous.

It is for this reason that simplified "languages" were invented to communicate with computers. Recall that the binary language (also known as machine language) is the easiest language for a computer to understand. However, this language is hardly practical for people. Therefore, other languages have been invented to facilitate communications. These languages resemble common English and are called *high-level languages*.

For effective and clear communication with a computer, only a limited number of English words are used, as predefined commands. In addition, sentences or *statements* that specify instructions to a computer must obey strict grammatical rules, called the *syntax* of the language. The combination of a restricted vocabulary and a syntax is called a programming language. BASIC is one such language.

In summary, a *programming language* is a collection of rules (the syntax) and words and symbols (the vocabulary) that allow you to issue instructions to a computer in a format that can be understood exactly. A sequence of such instructions is called a *program*.





"Remember me? I'm the program and I'm made up of instructions."

Here is an example. Suppose we want to

```
add 2 + 2
```

and display the result. Using BASIC, we would write:

```
1 R = 2 + 2
2 PRINT R
```

where R stands for "result."

But wait . . . we said earlier that the only language that a computer can understand directly is *machine language;* and we are now issuing instructions to a computer in a language close to English. Isn't there a contradiction?

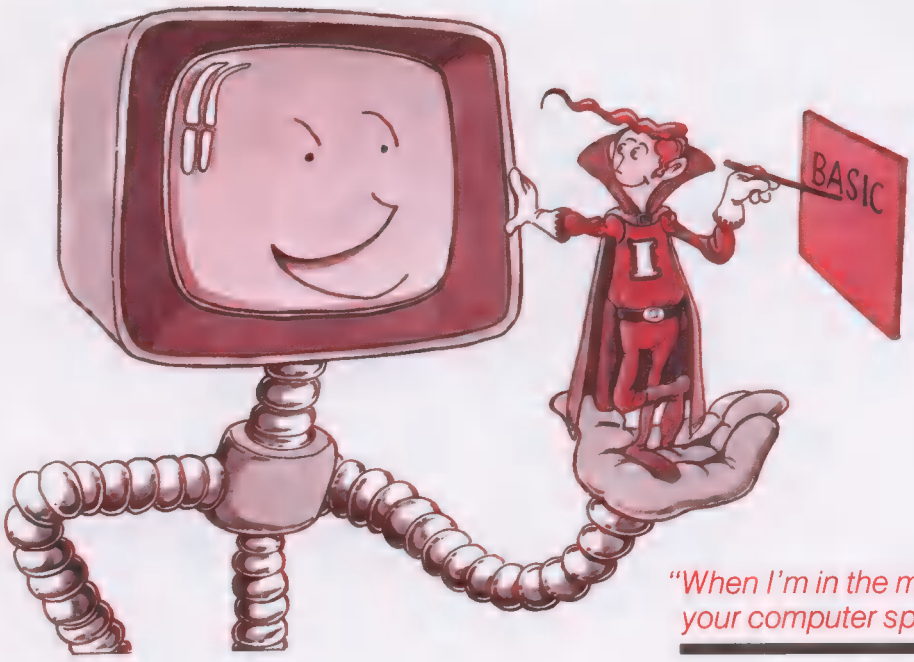
There is no contradiction. Indeed the bare computer cannot understand BASIC directly, or for that matter, any other high-level programming language (a language that uses English-like sentences). Therefore, to be understood by a computer, a program written in a high-level language, such as BASIC, must be *interpreted* by a special program, called quite appropriately an *interpreter.* In other words, you speak BASIC to your computer via an interpreter. Therefore, in order to execute a BASIC program, your computer must have a BASIC interpreter. Let's now learn what an interpreter does.

"Remember me? I'm the BASIC interpreter, ready to translate your instructions to the computer. I'm a program, and I'll reside in your computer's memory."

The BASIC Interpreter

A BASIC interpreter reads each BASIC instruction you type at the keyboard, analyzes it, and uses its own special procedures to carry it out. This process is completely invisible to you (i.e., it takes place inside your computer). Once you activate the interpreter program on your computer, for all practical purposes, your computer can speak BASIC. Your Atari computer is able to speak other programming languages as well (such as PILOT and LOGO),if the appropriate interpreters are provided.

The memory of a computer must contain the programs, including the BASIC interpreter, and also provide sufficient space for computations, system management, and data to be operated on. These space requirements limit the size, and therefore restrict the complexity, of the interpreter, if it resides permanently in the memory of the computer.



"When I'm in the memory, your computer speaks BASIC."

If you have an Atari 400, 800, or 1200XL, your BASIC interpreter is kept on a cartridge. After you install the cartridge in your Atari, the computer will automatically use the BASIC interpreter as soon as you turn your computer on. If you have one of the newer Atari computers (the 600XL, 800XL, 1400XL, or 1450XLD), Atari BASIC is built right into the machine. The language is identical to that on the cartridge, but you don't have to plug anything in to use it.

Let us now explain what BASIC is, how it was invented, and the resulting dialects.

What is BASIC?

High-level languages were invented to make it easier for a user to give instructions to a computer, that is, to program it. Over the years, hundreds of programming languages have been invented.

In the early days computers were used primarily for scientific purposes, and the early programming languages were designed to facilitate numerical computations. Thus, the granddaddy of languages, FORTRAN ("FORmula TRANslator"), was designed purposely to specify numerical computations. FORTRAN, however, suffered from many drawbacks, and many new languages were invented. BASIC was one such language; COBOL, APL and Pascal were others that became widely used.

The invention of BASIC represented a major breakthrough. BASIC was designed to be simple and easy to learn. In addition, it is *interactive*. Let's see what this means.

BASIC stands for **B**eginners **A**ll-purpose **S**ymbolic **I**nstruction **C**ode. It was invented in 1964 by John Kemeny and Thomas Kurtz at Dartmouth College, working under a National Science Foundation grant. The goal of the authors was to design a language that could be used easily by a beginner. They succeeded in reaching this goal. To this day, BASIC is one of the easiest programming languages to learn.

Because BASIC was designed to be interactive—in fact it was the first interactive language—a user could interact with the program at a terminal, rather than submit batches of perforated IBM cards, as with older languages. BASIC originally ran on the GE225 time-sharing system at Dartmouth College. Terminals were available throughout the campus, and many users could access the computer simultaneously.

The success of BASIC was rapid. General Electric (GE) immediately decided to use it commercially. Kemeny and Kurtz published the first book on BASIC in 1967. And, Hewlett Packard (HP) and Digital Equipment Corporation (DEC) decided to make BASIC available on most of their computers.

BASIC offers two major advantages over languages like FORTRAN:

1. **For a user:** BASIC is the easiest language to learn, *especially* for a beginner.
2. **For a manufacturer:** BASIC is the easiest language to provide on a computer. Since the language is simple, the interpreter is also simple and requires only a small amount of memory.

A third factor contributed to the enormous success of BASIC: the advent of low-cost microcomputers. When microcomputers became widely available in the late 1970's, BASIC became the universal programming language on these small computers. Because the BASIC interpreter for a simplified version of BASIC requires only

4K (4,096 bytes) of memory, even the smallest computers could accommodate a resident BASIC. (Remember that a resident BASIC refers to an interpreter stored in the permanent memory of the computer.) The larger more recent computers have larger memories (64K and more—where 1K refers to 1,024 bytes) and can, thus, provide more powerful versions of BASIC.

Today BASIC is used on almost all computers. Over the years manufacturers have added extensions and "features" to the language, so that today the BASIC language is probably the most non-standard computer language. No two BASICs are the same. In fact, BASIC has become a family of languages and is no longer a single language. Although many standards have been proposed, none has succeeded, and none is likely to succeed at this late date. Does this mean then that you must relearn BASIC on each computer? Not quite. Once you know the essentials of BASIC that are common to all versions, you can easily learn the enhancements that each version offers. All BASIC's have essentially the same core of instructions. You will learn more about these instructions as you read on in this book.

Which BASIC?

There are two main types of BASIC: mini-BASIC and full BASIC or extended BASIC. Let's now briefly examine some of their differences.

A "mini" or "tiny BASIC" has fewer features and conveniences than a "full" or "extended BASIC." A usual limitation of a "mini-BASIC" is that it operates on integers only; that is, it does not handle fractional numbers. Such a version of BASIC is also called an "integer BASIC." By contrast, an improved version of BASIC that also handles fractional numbers is called a "floating-point BASIC." This feature is highly desirable if you plan to do computations.

A mini-BASIC will generally store information on cassette, but not on diskette. Also it will generally store programs, but not data—and as such it does not handle "files." Normally, it can only manipulate information that is part of a program or that is supplied at the keyboard. By contrast, a full BASIC used with disk units offers great convenience and power in handling collections of information (files) and programs.

Some manufacturers provide still more "advanced" versions of BASIC that are specific to the manufacturer. A user is generally alerted to this fact by the label "extended BASIC." This means that more powerful resources are available to the skilled programmer. An extended BASIC is available for Atari computers. However, the use of its special resources generally makes a BASIC program incompatible with other BASIC interpreters.

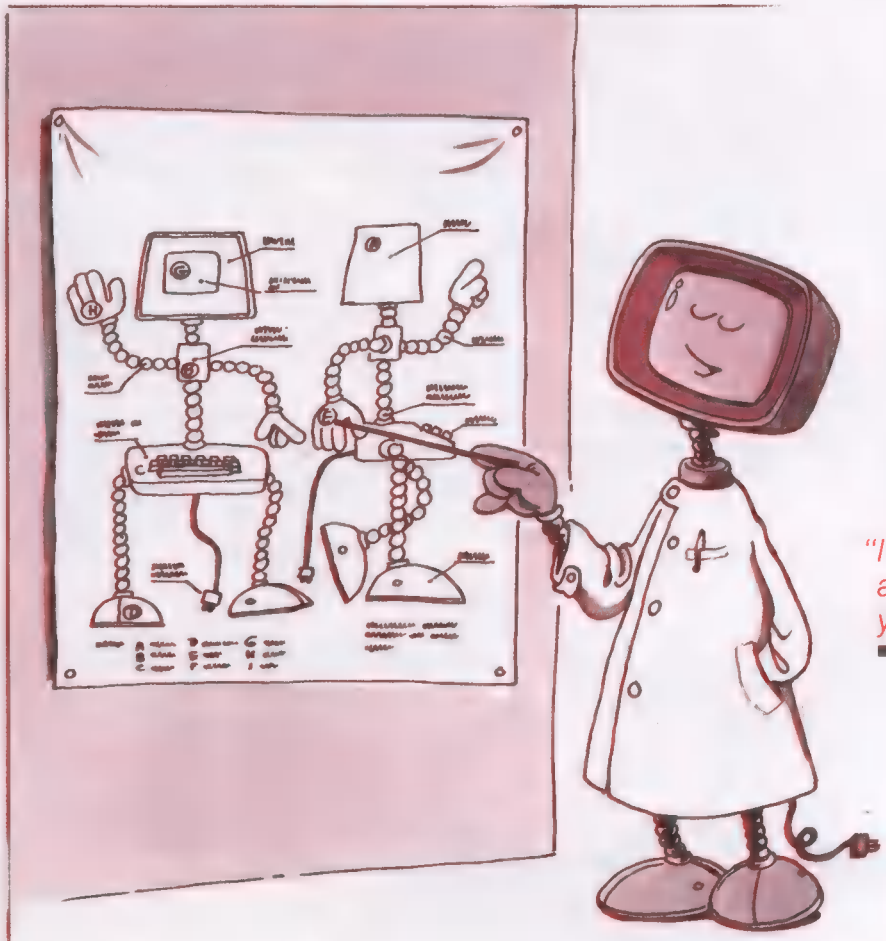
The BASIC used in this book is Atari BASIC. As we mentioned earlier, Atari BASIC may not come with your computer. You must purchase and insert an Atari BASIC cartridge on some models.

Once BASIC is in your computer, you can begin typing in and running all of the exercises and programs shown in this book. Doing this will give you skills in many of the main capabilities of Atari BASIC. A few of the features present in Atari BASIC (such as color graphics and sound) will not be covered in this book. Later, on, if you wish to write programs that employ these features, you can study the Atari BASIC manual.

Now that we understand more about programming languages in general and about Atari BASIC in particular, let's learn more about your computer and how it processes information.

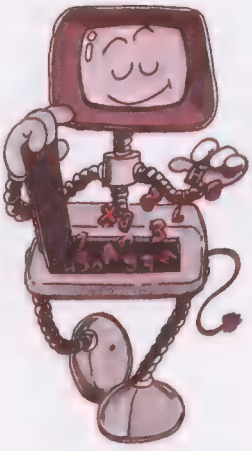
Your Computer

Your computer processes information and communicates with you via a keyboard and a television screen, plus maybe a printer. The *keyboard* is used to send information to the computer. Every time a

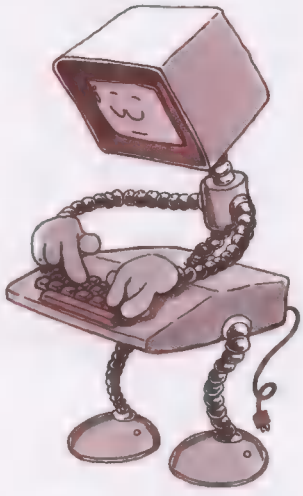


"I'm robust, helpful and friendly once you know me."

key is pressed, the electronic code corresponding to the character for that key is sent to the computer, where it is recognized and acted on, or ignored. The keyboard is your *input device;* it provides information to the computer.



"This is my keyboard."



"I need an input from you to know what to do."

The television *screen,* or *monitor,* displays information generated by the program. Normally, each character you press at the keyboard will appear on the screen. It is first sent to the computer, then "echoed" to the screen. There is no direct connection between the keyboard and the screen. All communications go through the computer. This is illustrated below.

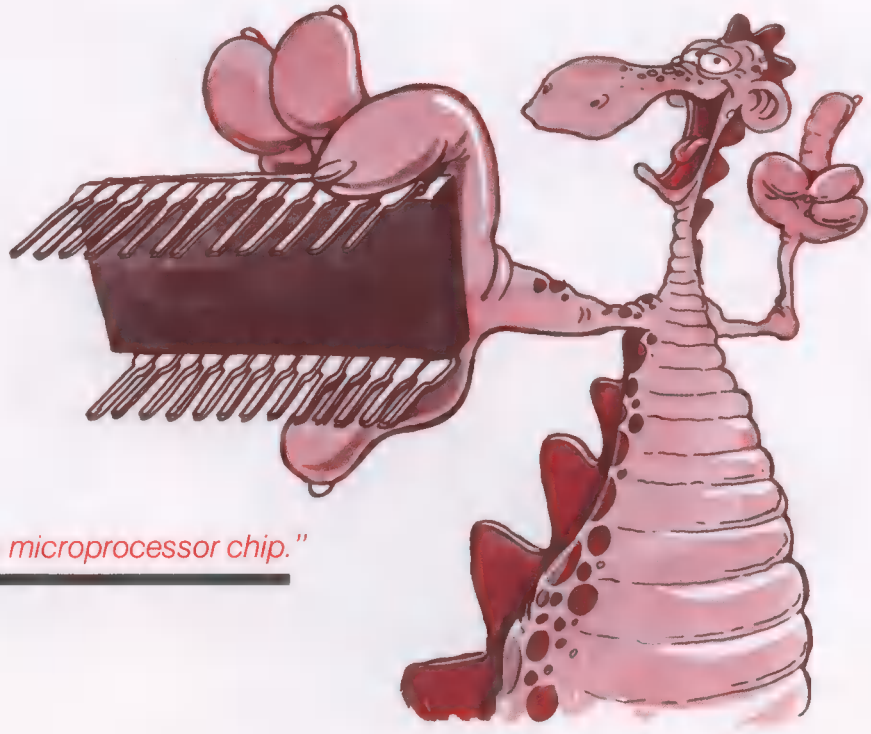
The keyboard sends information to the screen through the computer

Depending on your investment, your Atari computer may include a cassette recorder and/or disk units, and printer. Regardless of whether you have these extras or not, the computer proper includes a processing unit (the central processing unit), a memory, and several interfaces (the electronics for connecting printers and other devices). Let's examine these three elements.

The *central processing unit* (CPU) fetches program instructions, one instruction at a time, from the memory and executes them. The CPU requires few components, called integrated circuits or "chips". All microcomputers use a *microprocessor* chip as the main element of the CPU. A typical chip is shown in the drawing below.

The *memory* stores the programs and all the information that the programs manipulate, read, or generate during their execution. To execute a program, the program must first be placed in the computer's memory. For example, if a program is originally stored on a cassette or a diskette, it must be transferred into the computer's memory. This is called *loading* the program. There must be enough memory inside the computer to accommodate the largest program size, plus the data the program will manipulate.

Two types of memories are present in your computer: ROM and RAM. The "normal" type of memory that you will use to store your program is the RAM or random access memory. RAM is a read/write memory: information may be written into RAM and read from it. A RAM looks just like the microprocessor shown below except that there is a different chip inside. Unfortunately, in the present state of the technology, this type of memory is volatile: the contents of RAM disappear once the power is turned off. This is



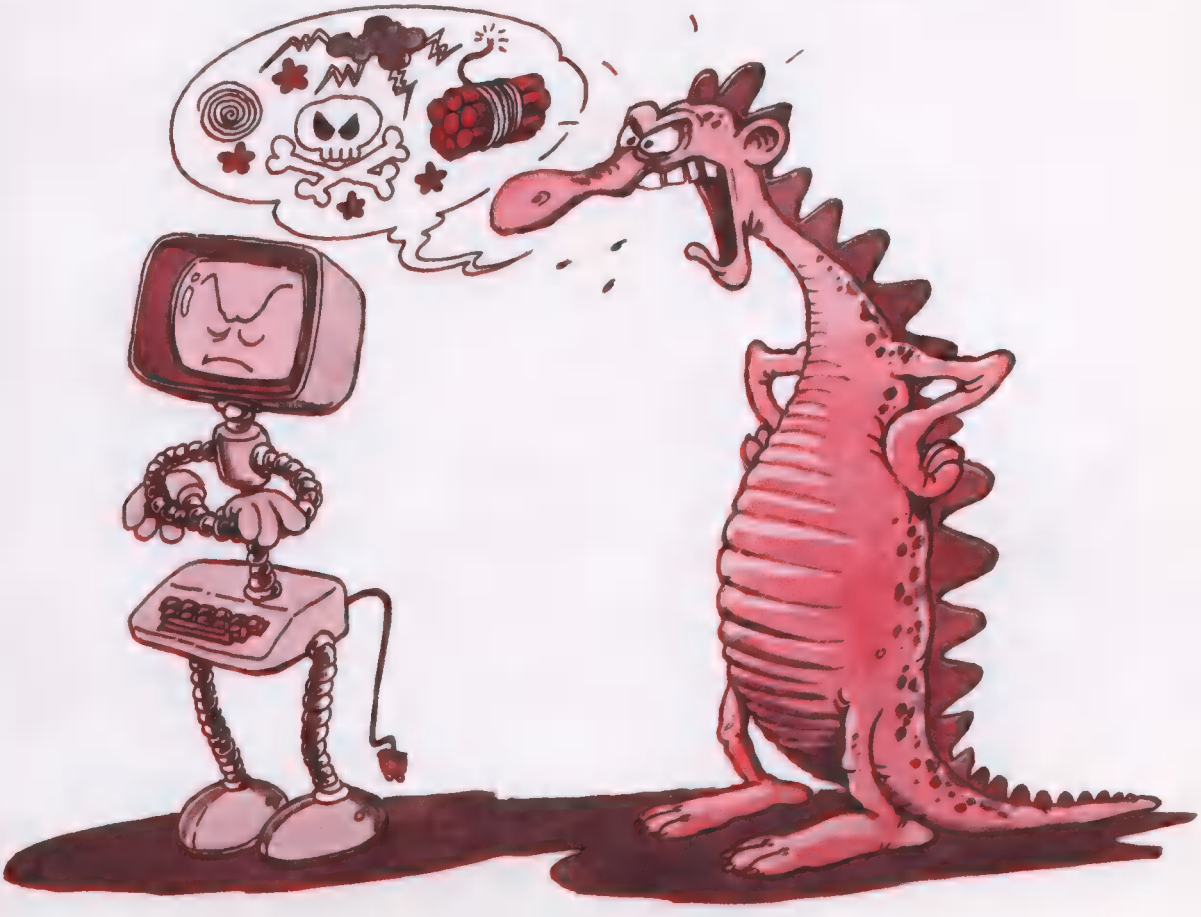
"This is a microprocessor chip."

why, at the end of a session, you must always store your program on a nonvolatile medium, such as a cassette or a diskette, if you want to keep it. Remember also that there must be a BASIC interpreter in the memory (in either RAM or ROM) before you can execute your BASIC program.

ROM stands for read-only memory. This type of memory has been permanently loaded with programs by the manufacturer and cannot be changed. It is nonvolatile and is never erased. It contains a special program, the *monitor,* which is needed to communicate with the computer once it is turned on.

If your ROM contains nothing, the computer will not know what to do when you press the keys on your keyboard. At a minimum, your ROM must contain a monitor. This monitor program examines the information sent by the keyboard, and reacts to it by

Your computer will do nothing until you enter a program in its memory



performing housekeeping actions, such as starting the resident BASIC interpreter or loading a program from a cassette.

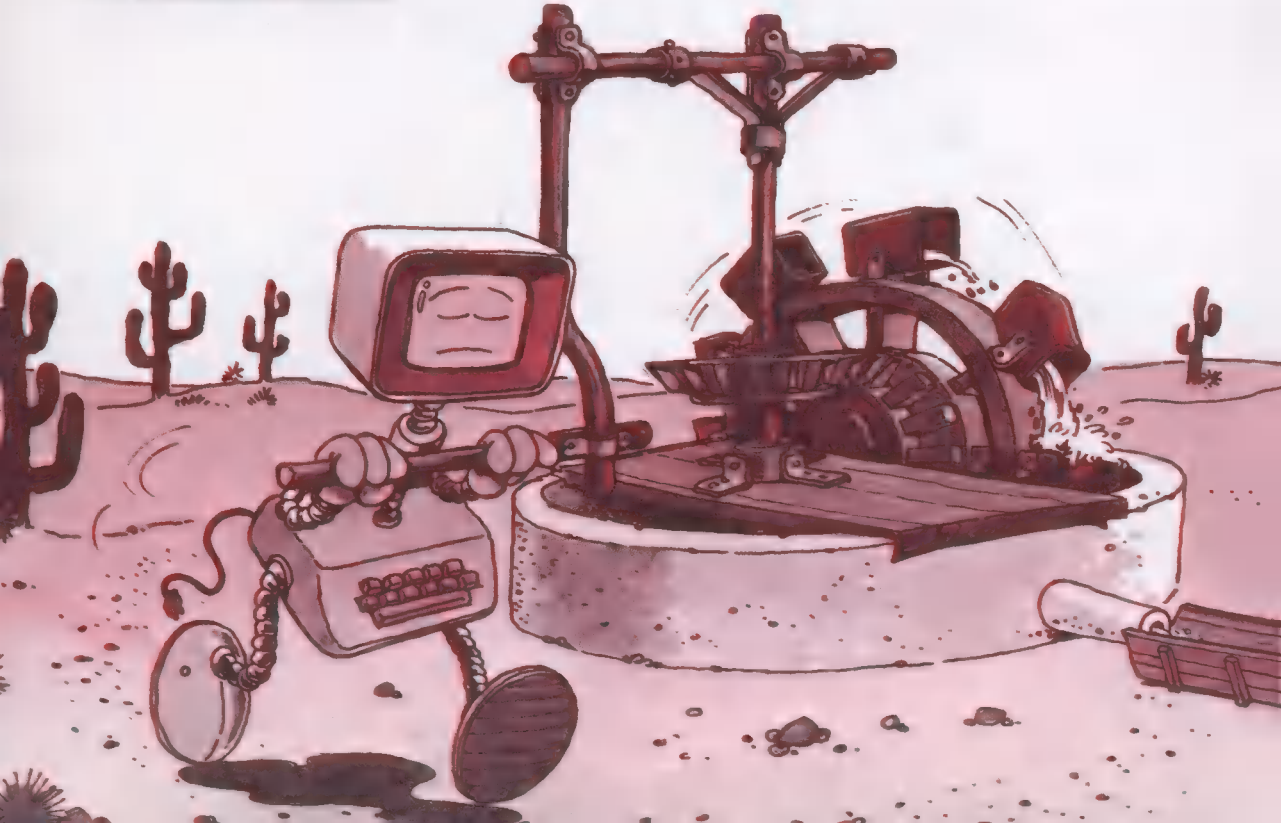
You cannot use the ROM to store any other programs. All other programs that you enter on your computer are loaded into RAM.

If your Atari BASIC interpreter is in a BASIC cartridge you install in the computer, the BASIC interpreter is stored in two ROM chips inside the cartridge. Otherwise the ROM chips are in the computer.

At least two additional devices are commonly connected to a computer: a mass memory and a printer. These devices connect through the *interfaces*—the electronics required to connect special devices. The mass storage device may be the Atari *program recorder* or one or more *disk drives*. (**Note:** Both of these devices use a magnetic medium to record information and can store much more information than the internal electronic memory of the computer.) These special devices require a specific interface that allows them to communicate with the computer. The Atari *program recorder*, the Atari disk drive, and the Atari printer all have the necessary interface circuitry built into them.

A printer is required to obtain a permanent printout of programs or results. A printer is an *output device,* just like a TV screen and specific instructions are provided in BASIC to send information to either the screen or the printer.

The monitor program runs all the time, ready to perform all common chores



Finally, a *modem* is another device often used. A modem allows you to communicate with another computer or terminal over ordinary telephone lines. It is useful when using a commercial network or for accessing *data banks* (collections of information).

We have now learned the required vocabulary. Before we go on to Chapter 2 and start using the computer, *one word of caution is in order.*

Computers and Syntax

Computers are fast, patient, and accurate. They do only what they are told to do, and they do it exactly. In order to communicate successfully with your computer you must be exact. If you make an error or a mistake in writing a BASIC instruction, you will not damage anything in the computer, but your program will not execute successfully. It will generally stop and say: "syntax error."

Recall that the *syntax* is the set of rules that specify the correct way to write a BASIC instruction. Syntax rules are rigid. For example, you may not use an approximate spelling. If the rules specify a period, you may not use a comma or a semi-colon instead. Each character is rigidly interpreted by the computer and has a precise meaning. Any deviation will mean failure, or, at the very least, unexpected results.

Remember that if you do not obey the rules exactly, your program will probably not run. Do not attempt to be creative. The rules are simple, straightforward, and easy to follow when writing program instructions. It is best to save your creativity for the overall program design and for planning the tasks you wish to accomplish. In short, it is important that you carefully follow the instructions and recommendations given in this book.

"Remember . . . be exact."

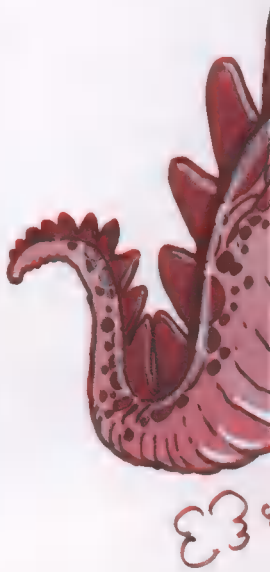
Communic
Your

2

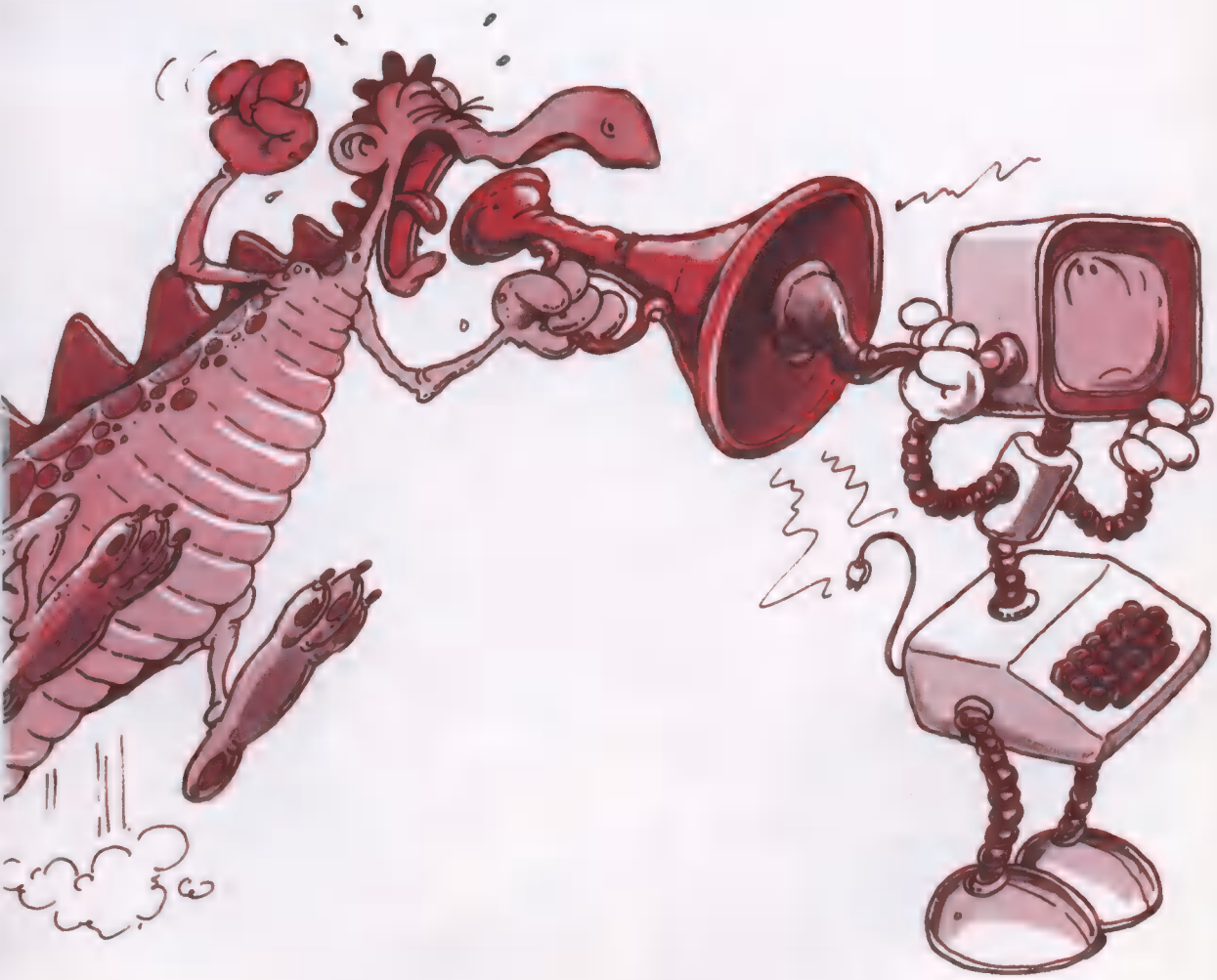
In this chapter, you will learn how to communicate with your computer. You will learn to issue BASIC instructions and make the computer display words and sentences. The information exchanged between you and the computer will include programs (instructions in BASIC that you send) and data (the numbers and characters that you send or receive).

You will first learn how to use the keyboard of a computer, so that you can start sending instructions. In particular, you will learn how to move the cursor around the screen, and how to correct typing errors. You will then issue your first instructions in BASIC and make the computer display messages on the screen. You will learn the difference between *immediate* and *deferred* execution. Finally, you will learn the steps involved in writing a simple program and in executing it.

By the end of this chapter, you should be familiar with the basic skills required to communicate with your computer.



cating with Computer



Using the Keyboard

The Atari keyboard looks just like a regular keyboard, except that it has extra keys. Most of its features are similar to those found on other computers, but it also has a few unique ones.

The main keys are:

1. the letters of the alphabet (A through Z)
2. the digits 0 through 9
3. symbols, such as =, +, *, ", and $
4. a "carriage return" key marked RETURN
5. ■ SHIFT key, and a control key marked CTRL
6. a delete key marked DELETE BACK S, an escape key marked ESC, and a BREAK key.

We will now examine the role and the use of all these keys.

Learn about the keyboard

Characters, Numbers and Symbols

The purpose of each *letter, number* and *special symbol* key is obvious. These keys are used for the same purposes as on a regular typewriter.

Carriage Return

On a typewriter, the carriage return lever or key performs two actions: it returns the carriage to the beginning of a line, and it advances the paper to the next line. Hence its name. On the Atari, however, the RETURN key generally moves the *cursor* to the beginning of the next line on the screen. (The cursor is the solid square that indicates the next position at which a character will be displayed on the screen.) The RETURN key could appropriately be called the ENTER key, since its main function is to ENTER a character or a line of text or data into the computer's memory.

Each instruction to the computer, including BASIC instructions, must be terminated with a RETURN. The RETURN means, "enter the line into memory." In fact, anything you type on a line is ignored by the computer until you press RETURN. This way, you can correct any errors you may have made, before you enter the line into the computer's memory.

RETURNs are used only at typing time. Although necessary, a RETURN is not stored as part of a program instruction. In this introductory chapter, to help you learn, we will show all the characters you must type, and display a symbol indicating RETURN at the end of each line. This symbol will appear as

Remember: you must press the RETURN key to transmit an instruction to the computer or else nothing will happen. Similarly when the computer later asks you for values, you enter each response by pressing RETURN as well.

Shift

Your Atari keyboard normally generates uppercase lettters. Since Atari BASIC requires that instructions be written in uppercase letters, throughout this book we will use only uppercase letters in our programs. Atari BASIC does, however, allow the use of lowercase letters for comments and text. To generate lowercase letters on the Atari, press the CAPS/LOWR key, located directly beneath the RETURN key. Note that the CAPS/LOWR key affects letters only.

To generate uppercase symbols and functions (such as $, ", and !), you must depress and hold the SHIFT key while typing the appropriate keys.

The SHIFT key on the Atari is also used in conjunction with other keys to perform special functions. For example, if you hold down the SHIFT key and press the CLEAR key, the screen will go blank, and the cursor will appear in the upper left-hand corner of the screen.

Let's now practice what we have just learned. Go to your keyboard, and hit keys at random. Press any key; you won't damage anything. Use the SHIFT key, and watch the characters being displayed on the screen. Now, press RETURN, and see what happens.

Control

The Control (CTRL) key is provided to issue frequently used commands to your computer in shorthand. It does not exist on typewriters. On the Atari, the CTRL key is used for editing program lines, setting and clearing tabs, stopping and restarting program lists, and for displaying graphic characters. The CTRL key is used like the SHIFT key: by holding it down, and pushing another key on the keyboard at the same time. This is called generating a control character. For example, "CTRL A" is generated by holding down the CTRL key and the A key simultaneously. This is a convenient way to generate a command or control code—by pressing only two keys. (**Note:** *Control codes* are provided to facilitate the use of frequently used commands, such as moving the cursor around the screen, i.e., left, right, up, or down, by a position, a word, or a sentence—and for erasing or inserting a character or an entire line of text.) We will not use any control codes in this book.

Delete

As its name implies, the DELETE BACK S key can be used to perform two tasks: to delete (or erase) single characters or lines of text, and to move the cursor backwards. Pressing this key and the SHIFT key together will delete an entire line of text. Pressing only the DELETE BACK S key will erase the character to the left of the cursor and move the cursor back one space.

Break

Normally when you run a BASIC program, it does not stop until it is finished, or until it encounters a STOP or END command. However, there are times when the unexpected happens and you need to stop your program from executing before it is finished. You can do this by pressing the BREAK key, which will stop the program from running and send a message indicating the last program line that was executed.

The Function Keys

The function keys are so named because they perform special functions or activate special features when pressed. We have already discussed four of these keys: the CAPS/LOWR key, the BREAK key, the DELETE BACK S key, and the CLEAR key. Some additional special function keys are:

1. The REVERSE VIDEO key. This is the key with the Atari logo. Pressing this key causes the text to "reverse out" on the screen (that is, dark text will appear on a light background). Be careful not to press this key when writing a program, because Atari BASIC commands will not work if they are in reverse video. If you accidentally press the reverse video key, however, just press it again and the display will return to normal.
2. The escape (ESC) key. The ESC key allows you to enter certain commands into a program for later execution. It is also used in conjunction with other keys to produce special graphic characters.
3. The SYSTEM RESET key. This key is like a combination of BREAK and SHIFT-CLEAR. Pressing it stops program execution, clears the screen, and positions the cursor in the upper left-hand corner of the screen.

Other function keys include SET-CLR-TAB and INSERT. You may want to refer to your *Atari BASIC Reference Manual* for information about these keys.

The Cursor

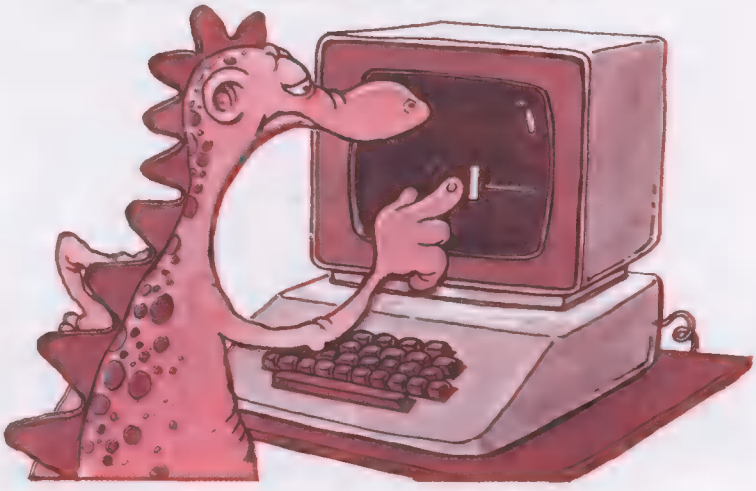
Recall that the cursor is the solid square on the screen that shows your current position. Here is the cursor showing you where you are on the screen after you have typed HELLO:

```
READY
HELLO■
```

By moving the cursor back and forth and up and down on the screen, you can type over characters and modify any text you have typed previously. This is a great convenience for making changes. You will use the cursor and the DELETE BACK S key extensively to correct typing errors.

Note: You can move the cursor in any direction without affecting the characters on the screen by holding down the CTRL key and pressing the four arrow keys: →, ↓, ←, ↑.

Learn to move the cursor on the screen



You may now want to go back to your keyboard and practice some of the things you have just learned. When you feel reasonably familiar with your keyboard, come back and learn how to issue BASIC instructions to the computer.

Speaking BASIC

Recall that to speak BASIC to older model Ataris you must install the BASIC cartridge in your computer, whereas newer models have a built-in interpreter. In either case, your Atari lets you know that Atari BASIC is ready to use when you see the following message:

```
READY
■
```

The word READY, together with the solid cursor is a *prompt*. The prompt is a message from the BASIC interpreter; it means, "I'm ready. Go ahead and tell me what to do." As soon as you see this message, you know that your Atari BASIC interpreter is ready and waiting for your instructions.

We will now proceed, assuming that:

1. Your Atari computer is turned on, with the BASIC cartridge installed if necessary.
2. The Atari BASIC prompt appears on your screen. If the prompt does not appear, press the SYSTEM RESET button and see what happens. If this does not work, turn your computer off, and restart it.

We will now issue our first BASIC instruction to the computer. Type the following (exactly as it appears here):

```
PRINT "HELLO"
```

The screen should look like this:

```
READY
PRINT "HELLO"■
```

The word READY is the *prompt*. The characters below have just been typed by you. Nothing should happen yet. Do you remember why?

This is because you must hit the RETURN key to *enter* your instruction. Now press RETURN. Your screen should look like this:

```
READY
PRINT "HELLO"
HELLO

READY
■
```

The interpreter has received your instruction and has immediately executed it by displaying HELLO as requested. Next, the

interpreter displays a new prompt (■), telling you it is ready for a new instruction.

Let's examine our first BASIC instruction more closely:

```
PRINT "HELLO"
```

This instruction has two parts: PRINT and "HELLO". PRINT is a *reserved word* that has a specific meaning to the BASIC interpreter. "HELLO" is the message to be PRINTed. It must be enclosed in quotes. You can use any message within the quotes. Let's try another. Type:

```
PRINT "THIS IS ANOTHER TEST" ↵
```

The following should appear on your screen:

```
READY
PRINT "THIS IS ANOTHER TEST"
THIS IS ANOTHER TEST

READY
■
```

Try again. Display your own message, but remember: if you forget one of the quotes or if you misspell PRINT, it will not work, and you will get an error message. Go ahead; try it. You won't damage anything.

You may now be wondering why this instruction is called "PRINT" when in fact it merely displays, and does not print, the information on your screen. Even if you have a printer connected to your computer, nothing will be printed. You have probably guessed the reason. The early terminals were typewriter-like, and in fact, did print (not display) the information. And, although the technology has changed, the BASIC instruction has not. Another BASIC instruction is now used to send information to the printer, rather than to the display. This instruction is called LPRINT, because its main use is to *list* programs on paper.

Before we proceed, make sure that the BASIC prompt appears on your screen, i.e., that the BASIC interpreter is ready to accept another command. If the prompt does not appear, you cannot execute a BASIC command. Try pressing RETURN or SYSTEM RESET, or if that doesn't work, try restarting your system.

We will now write our first BASIC program, rather than just execute a single instruction or "statement." Type the following:

```
10  PRINT "HELLO" ↵
20  PRINT "HOW ARE YOU?" ↵
30  END ↵
```

Your screen should look like this:

```
READY
10  PRINT "HELLO"
20  PRINT "HOW ARE YOU?"
30  END
■
```

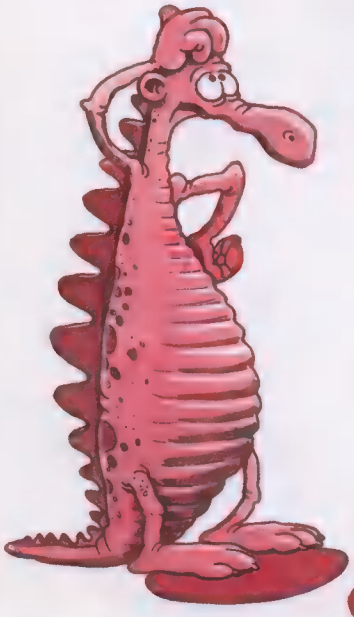
You may be surprised that nothing has happened. The computer merely responds with a ■. These three lines are more than just three BASIC statements. They constitute a short BASIC *program*. Note that each line begins with a number; this number is called a line number or *label*. It tells the computer that we want to write a complete program, and not execute each instruction immediately. Now, type:

```
RUN ↵
```

You should now see on your screen:

```
HELLO
HOW ARE YOU?

READY
■
```



"How does this work?"

How does this work? We first created a three-line program and stored it in memory, a line at a time, by pressing RETURN. We then executed the program by typing RUN. This is the normal way of writing and executing a program. We will follow this procedure from now on. All lines will be preceded by a numerical label, and the program will be executed automatically in the order of the labels.

If at any time you type an unlabeled BASIC statement in response to a ■, the statement will be executed immediately; it will not be memorized. This is called the *direct mode* in Atari BASIC. If at any time you type a labeled BASIC statement in response to a ■, the statement will be memorized when you hit RETURN, but not executed until you type RUN. This is called the *deferred* mode. Let's demonstrate how this works.

Our three-line program has been stored in memory. It can be executed any number of times, expanded or modified. Now, type:

```
RUN ↵
```

again, and you should see:

```
HELLO
HOW ARE YOU?

READY
■
```

Let's now examine the computer's memory and display its contents. To do this type:

```
LIST ↵
```

and you should see the following displayed on your screen:

```
10  PRINT "HELLO"
20  PRINT "HOW ARE YOU?"
30  END

READY
■
```

Your program is listed on the screen as it is stored in the computer's memory.

You can even save this first program on your cassette or diskette, if you have one.

To demonstrate the difference between direct and deferred instructions, type:

```
PRINT "GOOD BYE" ↵
```

You see on the screen:

```
READY
PRINT "GOODBYE"
GOODBYE

READY
■
```

Now type:

```
LIST ↵
```

again, and you should see on your screen:

```
10  PRINT "HELLO"
20  PRINT "HOW ARE YOU?"
30  END

READY
■
```

The new immediate instruction: PRINT "GOOD BYE" is nowhere to be seen. It has not been memorized.

If you haven't used a line number, the instruction is gone!

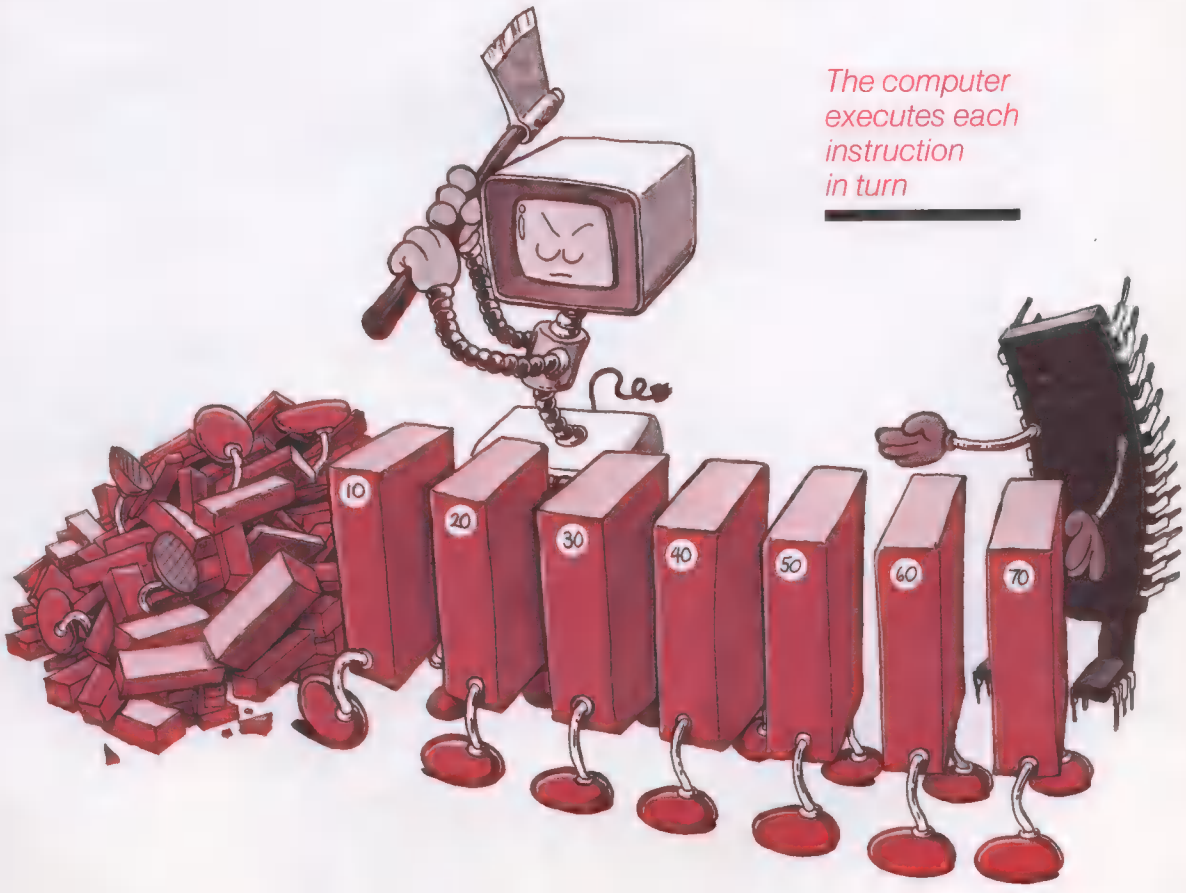
Program Summary

In summary, an immediate statement is executed as soon as you type it. It is not stored in the computer's memory, and you will need to type it every time you want to execute it. This facility is called the *direct* mode. In practice, this mode is used infrequently—generally when you want to verify some values after a program has stopped. Feel free to experiment by typing BASIC instructions and see what happens.

When a line is preceded by a label, the mode is called the *deferred execution* mode. In this mode, each line of the program is stored away in the computer's memory. When a complete program has been typed in, you simply issue the RUN command, and the entire program will be executed. Remember that when you turn the computer off, the contents of the RAM memory disappear, including any program you may have typed. If you wish to keep your program for later use, you must save it on a cassette or diskette.

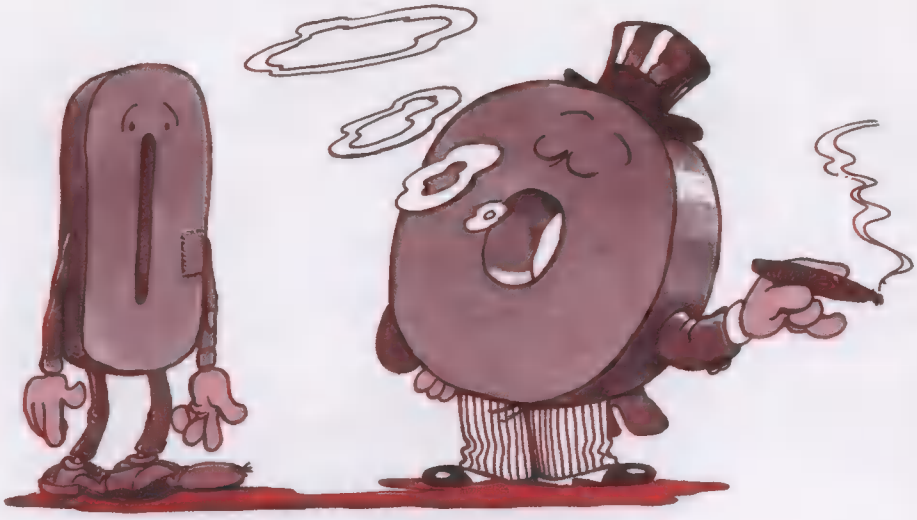
Each line of a BASIC program must start with a label. The label specifies the order in which the line will be executed. Thus, line 10 will be executed before line 20.

The END statement, line 30 in our example, is optional with Atari BASIC, but required with older BASICs. The END statement tells the interpreter that it has reached a legitimate END, rather than an accidental one, during execution. However, an Atari BASIC program that runs out of lines to execute will end all by itself.



The computer executes each instruction in turn

Don't confuse number 0 and letter O



As a final detail, note that the digit 0 must look different from the letter O. The traditional way to avoid confusion is to show the digit 0 as Ø, an O overstricken with a slash—and that is how it appears on the Atari.

A Longer Program

RUN, LIST, and SAVE are called *commands*. They are reserved words used by themselves to specify special actions carried out by the computer system, or more exactly by the interpreter. These commands are also part of BASIC. We will progressively learn more statements and commands as we continue through this book.

Let's now write a more complete program, using the PRINT statement and the NEW command. Type the following:

```
NEW ↵
```

Then:

```
LIST ↵
```

Nothing happens. There is no longer any program in the memory. The NEW command clears the computer's memory. Now type:

```
NEW ↵
10 PRINT "THIS" ↵
20 PRINT "IS" ↵
30 PRINT "ANOTHER" ↵
40 PRINT "EXAMPLE" ↵
50 END ↵
```

Let's find out what this program does. Type:

```
RUN ↵
```

You should now see on your screen:

```
THIS
IS
ANOTHER
EXAMPLE

READY
■
```

Our program displays the text as expected. Let's verify that the program has been stored correctly in memory by typing:

```
LIST ↵
```

You should now see on your screen:

```
10 PRINT "THIS"
20 PRINT "IS"
30 PRINT "ANOTHER"
40 PRINT "EXAMPLE"
50 END

READY
■
```

The NEW command has been used to clear the memory of the computer, i.e. to erase it, to make room for the new program. If the

NEW command is not used, the new statements would erase and replace any older statement with identical labels previously typed into memory. This could lead to errors since old statements might be "leftover" in a new program. If you do not use NEW, then every time you type a statement with the label 10, the new version will automatically erase any older version of that statement. But, *beware,* if you had previously written a statement with the label 15, then typed in the above program without a NEW, the statement "15" would remain in the computer's memory and would automatically be incorporated into your new program in sequence (since the label 15 is not used in the new program). Let us demonstrate this. Type:

```
15 PRINT "*****" ↵
```

Then:

```
RUN ↵
```

Your screen should look like this:

```
THIS
*****
IS
ANOTHER
EXAMPLE

READY
■
```

As you can see, the new PRINT statement, labeled 15, has been automatically inserted in the older program after statement 10. Let's list the program. Type:

```
LIST ↵
```

Your screen should look like this:

```
10 PRINT "THIS"
15 PRINT "*****"
20 PRINT "IS"
30 PRINT "ANOTHER"
40 PRINT "EXAMPLE"
50 END

READY
■
```

You just verified that statement 15 is now part of your program. Remember that every time you type a program statement with a label, it is automatically inserted in the memory of the computer in the proper sequence.

We will now demonstrate that when you use a label number that *already exists,* your new statement will automatically erase the previous one. Let's now use this feature to erase statement 15. Type:

```
15 PRINT "........" ↵
```

Then:

```
RUN ↵
```

Your screen should look like this:

```
THIS
........
IS
ANOTHER
EXAMPLE

READY
■
```

As you can see, your new PRINT statement with the label 15 has superseded the previous one. Verify it by typing:

```
LIST ↵
```

Your screen should look like this:

```
10 PRINT "THIS"
15 PRINT "........"
20 PRINT "IS"
30 PRINT "ANOTHER"
40 PRINT "EXAMPLE"
50 END

READY
■
```

To avoid accidents, whenever you write a new program, you should use the NEW statement to clear your computer's memory and avoid interference by "leftover" statements from previous use.

"That's how I erase!"

Let's now erase statement 15. There are many ways to do this. Here we will type:

```
15 ↵
```

This statement merely consists of a label. This is called an *empty statement.* Statement 15 does nothing, except erase any previous version. Now type RUN. You should see the following on your screen:

```
THIS
IS
ANOTHER
EXAMPLE

READY
■
```

Be careful. This feature can be dangerous. If you type:

```
20 ↵
```

by accident, you will erase the previous version of statement 20, and replace it with an "empty" statement that does nothing. To avoid surprises, always verify your program listing prior to execution.

Summary

We have now learned how to write elementary BASIC programs that display information on the screen. We have written a BASIC program using labeled statements. We have discussed why programs should be preceded with the NEW command and terminated with the END statement. We have seen that a program is stored automatically in the computer's memory as it is entered, and that it can be executed by typing the RUN command. We have also seen how a program listing can be displayed with the LIST command. Finally, we know we can use the SAVE command to save a program on cassette or diskette.

We have learned that the execution of program statements is in the order of the labels. If you duplicate a label number either intentionally or by mistake, the new statement will automatically erase any previous statement with the same label number. Also, if at any time you add a line with a new label, the interpreter will automatically insert it in its proper sequence within the program.

In this chapter, we have introduced many new concepts. If you truly want to learn how to program, it is essential that you start practicing what you have learned. Several self-test exercises follow. You are strongly encouraged to try them out. Answers to selected exercises are given at the end of this book.

Exercises

2-1: Write a program that prints the following: "HAVE A GOOD DAY."

2-2: Write a program that prints:

```
AAAAA
BBBB
CCC
DD
E
```

2-3: Write a program that prints:

```
*******
*TITLE*
*******
```

2-4: Define the following terms:

a. label

b. deferred execution

c. direct execution

d. empty statement

e. cursor

f. control key

g. reserved word

h. prompt

2-5: What is the difference between PRINT and LPRINT?

2-6: Can you execute a whole program by typing statements one at a time in the direct mode?

2-7: Why use NEW before typing a new program?

2-8: Can you type labeled program statements out of sequence?

2-9: Give examples of some Atari BASIC commands.

2-10: Is the following statement a valid way to display the word EXAMPLE?

```
PRINT EXAMPLE
```

2-11: What is the use of the RETURN key?

2-12: Explain how to erase statement 20 in a program.

2-13: If you have already typed statement 30 and wish to substitute a new statement 30, do you have to erase the old one first?

2-14: Write a program that displays the following:

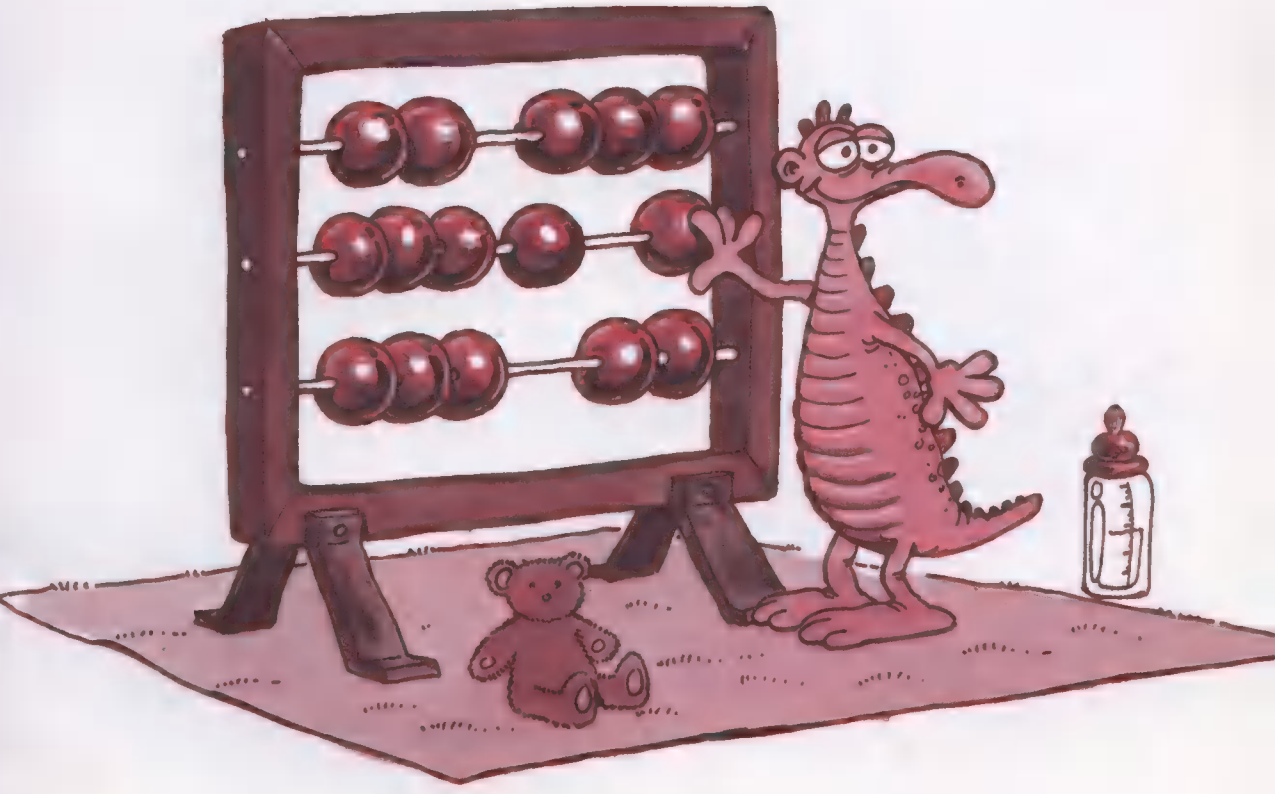
```
TTTTTT   H   H   EEEEEE
  TT     H   H   EE
  TT     H   H   EE
  TT     HHHH    EEEE
  TT     H   H   EE
  TT     H   H   EE
  TT     H   H   EEEEEE
```

Calculat

3

In this chapter, we will start using numbers. We will display them and add, subtract, multiply, and divide them. We will learn to perform computations using the simple arithmetic operators, and we will describe the other important built-in operators in BASIC.

ing with BASIC



Printing Numbers

So far we have only printed text. Let's now print a number. Type:

```
PRINT 3
```

The result should be:

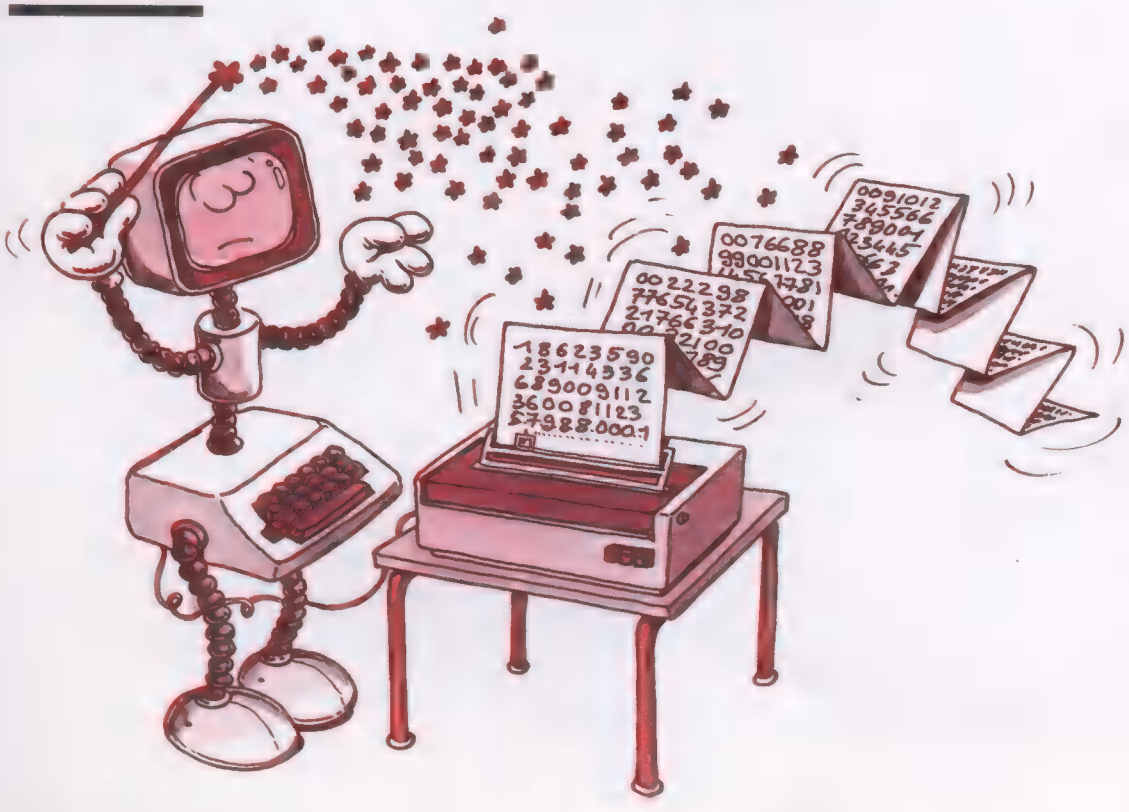
```
3
```

Recall from our discussion in Chapter 2 that this statement is in the immediate mode, where an instruction does not need to be preceded by a label and is executed immediately. In this chapter, we will write all of the examples in the immediate mode, so that you can execute them by pressing only a few keys.

Notice that in BASIC, numbers do not need to be enclosed in quotes, only text. The use of quotes allows the interpreter to easily differentiate between user-provided text and the BASIC reserved words, such as PRINT. The text inside the quotes is called a *string*, and a string may include numbers.

Let's now try to print several large numbers, say 100, 1000, 10000, etc. When you try to print a number with more than ten digits, you will notice that something odd happens—a decimal point appears to the right of the first digit, an "E" appears after the last digit, followed by a plus sign and a number. Your Atari BASIC interpreter has converted your number into scientific notation. We'll discuss scientific notation shortly.

"I'll show you more ways to print numbers."



Let's find out if the Atari BASIC interpreter allows decimal numbers. Type:

```
PRINT 1.5
```

Since you now see 1.5 displayed on your screen, you know your BASIC interpreter can handle decimal numbers.

In computer jargon, decimal numbers are called *floating-point numbers*. A BASIC interpreter that allows the use of floating-point numbers is called *floating-point BASIC*. Atari BASIC is a floating-point BASIC.

Scientific Notation

Let's discuss decimal numbers further. As with integers, in the case of decimal numbers, the interpreter will only retain a set number of digits. For example, the correct value of one third is:

```
0.33333333333 . . .    (etc.)
```

Inside the computer, this value is stored as:

```
0.333333333    (nine significant digits are retained besides the zero)
```

The correct value is said to have been *truncated* (cut) to nine digits.

Your Atari BASIC interpreter allows decimal numbers; it also uses a *scientific representation* for these numbers. When a number becomes very large or very small, it will be displayed in scientific notation to save space.

Here is an example:

```
3.2 E+06
```

means

$3.2 \times 10^{6} = 3200000$

10^{6} means 10 to the power 6, i.e., 10 multiplied 5 times by itself:

$10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1000000$

Similarly

```
1.12 E-07
```

means

$1.12 \times 10^{-7} = 0.000000112$

10^{-7} means 1/10 to the power 7, i.e., 1/10 multiplied 6 times by itself (1/10 is 10^{-1}).

Using scientific notation, your Atari BASIC interpreter can handle numbers as small as 10×10^{-98} and numbers as large as 10×10^{99}!

Doing Arithmetic

Let's now perform simple arithmetic calculations. Type:

```
PRINT 2 + 2 ↵.
```

The result appearing on your screen should be:

```
 4
```

We have just performed our first arithmetic computation. The addition symbol, + , is called an *operator.* An operator is a symbol that represents an operation to be performed on one or more operands. BASIC provides at least five built-in arithmetic operators:

–	*(minus)*
+	*(plus)*
*	*(multiplication)*
/	*(division)*
^	*(exponentiation or power)*

"You need more practice."

Now try this example. Type:

```
PRINT 2 * 3
```

The result should be 6. The * symbol is the symbol for multiplication. The usual multiplication symbol, ×, could be confused with the letter X, so programming languages use the * symbol instead.

Here are other examples of valid arithmetic statements:

```
PRINT 1 + 2 * 3
```

The result is

```
7
```

```
PRINT 3 - 2
```

The result is

```
1
```

```
PRINT 8/2
```

The result is

```
4
```

```
PRINT 1 + 2 + 3 + 4
```

The result is

```
10
```

Since Atari BASIC allows decimal numbers, the following statement is also legal:

```
PRINT (6/3 + 12/4)/2
```

The result is

```
2.5
```

Note that parentheses have been used in this example to clarify the

grouping of operations. Let's try another example. Type:

```
PRINT 2 + 3 + 4/2 ↵
```

The result is:

```
7
```

The division (/) was performed first on the 4. This is due to the fact that in BASIC, if given a choice (i.e., if parentheses are not used), the division (/) or the multiplication (*) will take place before the addition (+) or the subtraction (-). If you had intended to divide the group 2 + 3 + 4 by 2, then it would have been necessary to type:

```
PRINT (2 + 3 + 4)/2 ↵
```

The result would then be:

```
4.5
```

The division would then have been performed on the group (2 + 3 + 4). It is good practice to use parentheses freely, to avoid any confusion. For example, the following expression (or group of values and operators)

$$\frac{1 + 2 + 3}{4 + 5} \times 3$$

could be translated into the following BASIC expression:

```
((1 + 2 + 3)/(4 + 5)) * 3
```

or

```
(1 + 2 + 3)/(4 + 5) * 3
```

because execution proceeds from left to right when operators have the same precedence (standing), i.e., the division occurs here before the multiplication.

If you were to write the following in BASIC:

```
(1 + 2 + 3)/((4 + 5) * 3)
```

it would be equivalent to:

$$\frac{1 + 2 + 3}{(4 + 5) \times 3}$$

Use parentheses to denote groups. Be sure to make sure there is always a matching right parenthesis for each left one.

Let's now use our new computing skill to display useful values.

Printing Formats

If you type:

```
PRINT "THE PRODUCT OF TWO AND THREE IS",  2 * 3 ↵
```

The result will be:

```
THE PRODUCT OF TWO AND THREE IS
  6
```

In the above PRINT statement, we have mixed text and numbers, separated by a comma. More precisely, we have used an *expression*, 2 * 3, rather than a number. Now, type:

```
PRINT "THE PRODUCT OF TWO AND THREE IS,  2 * 3" ↵
```

and you will get:

```
THE PRODUCT OF TWO AND THREE IS,  2 * 3
```

This is a valid BASIC statement, but not the one you had intended. Remember, everything within quotes is displayed literally. The comma or semicolon must be *outside the quotes* to work correctly.

A PRINT statement may be used to print several items on the same line. The items must, however, be separated by a semicolon or a comma. A semicolon will result in the items being printed on the same line but with no spaces between them, while a comma will result in a large space. Like a tab stop on a typewriter, the comma symbol is used to create *tabs,* i.e., fields on the screen. This technique is convenient for displaying tables.

Let's try this new feature. Type:

```
PRINT 1;2;3 ↵
```

Your display should show:

```
1 2 3
```

Now type:

```
PRINT 1,2,3 ↵
```

Your display should show:

```
1          2          3
```

Let's now compute the sales tax for a sale of $1234. The tax rate is 6.5%. The statement is:

```
PRINT "SALES TAX IS "; 1234 * 6.5 / 100
```

The result is:

```
SALES TAX IS 80.21
```

We could also type:

```
PRINT "SALES TAX IS "; 1234 * 0.065
```

and we would obtain the same result. There are many equivalent ways to write a program.

You can print many items on a line. Look:

```
PRINT 1;2;3;4;5;6;7;8;9;"MANY ITEMS"
```

The screen will show:

```
1 2 3 4 5 6 7 8 9 MANY ITEMS
```

We have now learned how to perform simple arithmetic computations, and how to display the results. Let's use this new skill to solve some simple problems.

Only feed reasonable numbers to your program

Application Examples

Let's compute a car's mileage in miles per gallon. The mathematical formula is:

```
MILEAGE = DISTANCE (in miles) ÷ GAS (in gallons)
```

Let's assume that the distance was 510 miles and the amount of gasoline used was 20.2 gallons. Here is the statement written in BASIC:

```
PRINT "MILEAGE IS "; 510 / 20.2 ; "MPG" ↵
```

For metric readers we will now convert this into liters per kilometer. One gallon is 3.8 liters. One mile is 1.6 kilometers. The consumption in liters per kilometer is:

```
PRINT "GAS CONSUMPTION IS "; (20.2*3.8) / (510*1.6) ; "L PER KM" ↵
```

Here is another simple problem. Given a temperature in Fahrenheit, the Celsius equivalent is computed by the formula:

```
CELSIUS value = (FAHRENHEIT value – 32) × 5/9
```

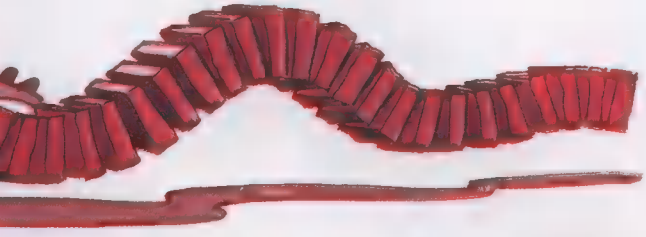
To compute the Celsius equivalent of 79° F, type:

```
PRINT "79 DEGREES F = "; (79 – 32) * 5/9; " DEGREES C" ↵
```

The result is:

```
79 DEGREES F = 26.11111111 DEGREES C
```

To be complete, note that 5/9 has not been enclosed in parentheses, as it does not matter whether * or / is executed first.



Summary

In this chapter, we have learned how to perform arithmetic computations and how to display text and results on the same line. We have used this new skill to automate the computation of simple formulas by writing one-line BASIC statements.

So far we have specified all the values within the BASIC statement itself. What we now want to do is first write a program, then supply values repeatedly from the keyboard so different values can be used with the program without having to rewrite it. We will accomplish this with *variables*. This is the topic of the next chapter.

Exercises

3-1: Write a BASIC statement that computes:

$$\frac{5 + 6}{1 + 2 \div 3}$$

3-2: Write a BASIC statement that computes:

$$1 + \frac{1}{1 + \frac{1}{2}}$$

3-3: Write a BASIC statement that computes the Fahrenheit equivalent of 20° C.

3-4: Given a speed of 100 km per hour, compute the equivalent speed in m.p.h. (1 mile = 1.6 km)

3-5: Compute the number of seconds in a day, a week, a month, and a year.

3-6: Assuming an average speed of 55 m.p.h., compute the time needed to travel 350 miles.

3-7: Assuming 365 days in a year, compute the number of days you have lived so far.

3-8: Compute the equivalent annual salary for a person, given the:

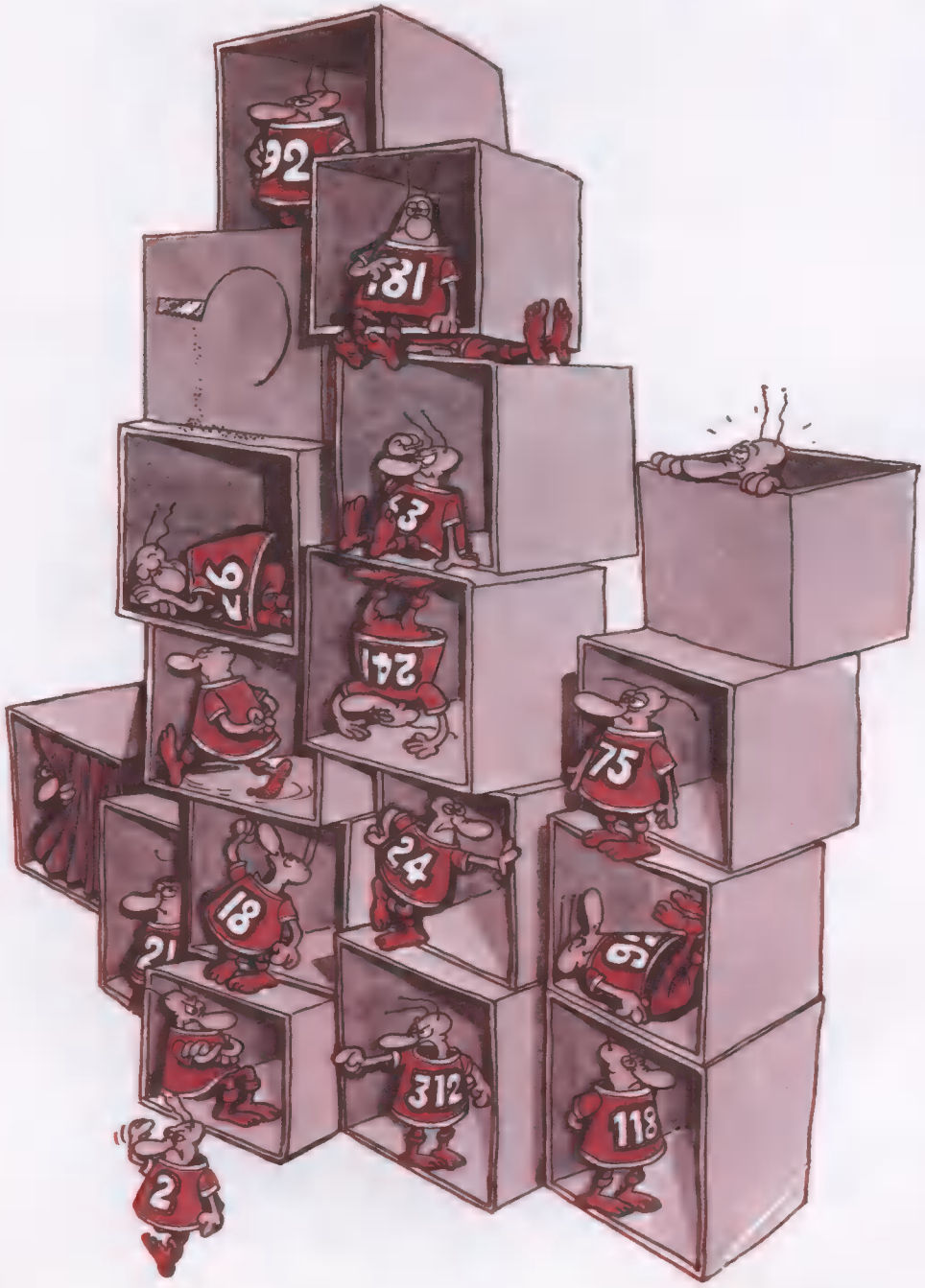
a. weekly pay (there are 52 weeks in a year)

b. biweekly pay (multiply by 26)

c. monthly pay

d. hourly pay (multiply by 2080)

Memorizing
Usi



Values and ng Variables

4

In this chapter, we will learn to write programs that can be used repeatedly, without change, and that will display different results, depending on the data supplied at the keyboard. So far, to obtain the result of an arithmetic computation, such as 2 + 3, we have had to include in the program statement the numbers to be operated on. We will now learn to write programs that can be executed with different data each time. The programs will specify the operations to be performed. The data will be supplied at the keyboard by the user at the time the program is executed. This makes the program reusable.

In addition, we will introduce the concept of a variable and learn how to use two new statements: INPUT and LET.

Let's now begin by learning how to supply information to a program while it is running.

The INPUT Statement

Type the following program. (**Note:** we will no longer display ↵ to indicate RETURN at the end of each line):

```
10 INPUT A
20 PRINT A;  2 * A;  3 * A
30 END
```

Now execute this program by typing RUN, ↵ as usual. Your screen should look like this:

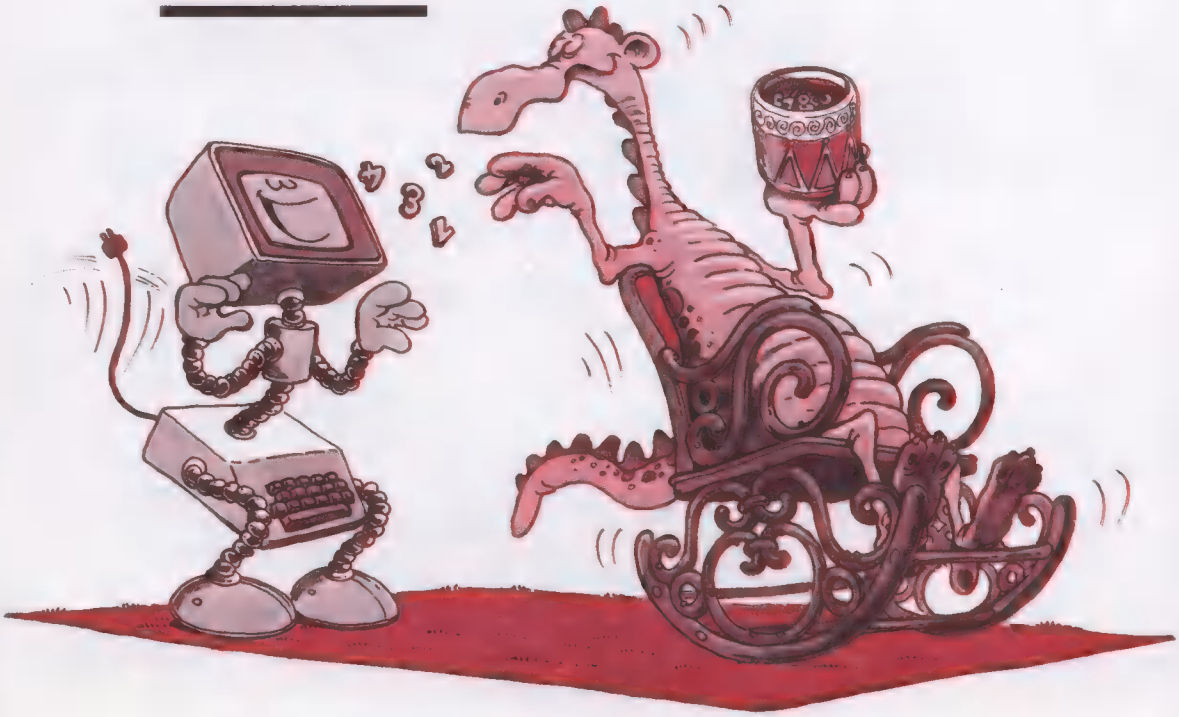
```
? ■
```

A "?" appears on your screen with a blinking cursor next to it to remind you to type in the input.

Now, type in a number, say 3. Terminate your input by pressing the RETURN key as usual. Your screen should now show:

```
3 6 9
```

On INPUT, your computer accepts numbers and letters



Your program has been executed. Let's see what happened. The first line was:

```
10 INPUT A
```

This statement asked you to provide a number at the keyboard. The program displayed a ?, and stopped—waiting for your input. The value 3 you supplied was then read and stored in A. "A" is called a *variable.* It is a name used to store a value. Formally, a *variable* is a name given to a memory location. Examples of some variable names are: A, B, C, F, Z1, G2. Atari BASIC allows variable names with several letters as well, for example: NUMBER1, SUM, TAX, RESULT.

The second statement was:

```
20 PRINT A; 2 * A; 3 * A
```

This statement resulted in the printing of 3; 2 * 3, 3 * 3, or:

```
3 6 9
```

Using the INPUT statement, it is also possible to enter several values at the same time. Here is an example. Type:

```
10 INPUT A,B
20 PRINT A; A * 2; B; B * 2
30 END
```

Now run the program. You should see the usual "?" appearing on your screen. Type two numbers, say 2 and 3, separated by a comma, then press return. The result is:

```
2 4 3 6
```

Let us examine what happened. The first line of the program was:

```
10 INPUT A,B
```

This statement resulted in a request for two values from you, which were then stored in the variables A and B. Remember that variables are names of memory locations. The contents of A and B were initially empty, but they became 2 and 3, respectively. The second statement of the program was:

```
20 PRINT A; A * 2; B; B * 2
```

This statement resulted in printing the values: 2, 2 * 2, 3, 3 * 2, or:

```
 2  4  3  6
```

Let's try running this program again. This time try typing:

```
5,8
```

and the results should be:

```
 5  10  8  16
```

We can use this program repeatedly and obtain new results by typing in new values at the keyboard. We have made our program reusable by using variable names (A and B), instead of explicit values.

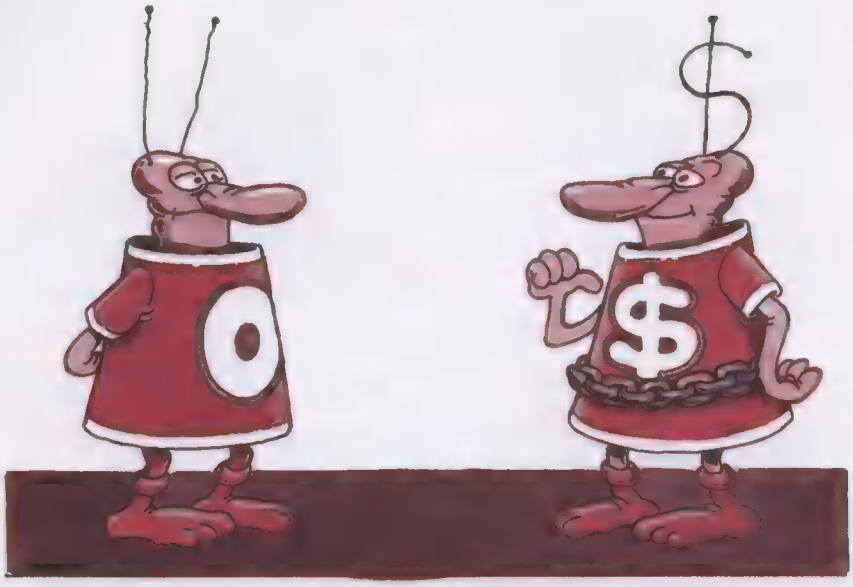
In order to make this program truly reusable, let's now improve its style and readability. Suppose that we want to save the program, and run it again in several days. We might forget what it does or we might not remember how many values we must supply. We can rewrite the program to display this information on the screen. Here is an improved version:

```
10  PRINT "THIS PROGRAM MULTIPLIES"
20  PRINT "ANY TWO NUMBERS BY 2"
30  PRINT "TYPE TWO NUMBERS"
40  INPUT A, B
50  PRINT "FIRST NUMBER : "; A; "DOUBLE :"; 2 * A
60  PRINT "SECOND NUMBER : "; B, "DOUBLE :"; 2 * B
70  END
```

and here is the resulting display: (**Note:** throughout this text, we will display data provided by the user in **boldface** type.)

```
THIS PROGRAM MULTIPLIES
ANY TWO NUMBERS BY 2
TYPE TWO NUMBERS
? 5,7
FIRST NUMBER  :  5          DOUBLE  :  10
SECOND NUMBER  :  7         DOUBLE  :  14
```

We have now learned how to supply numeric data to the program by using the INPUT statement. We have also introduced the concept of variable. Let's now learn how to use these techniques effectively and how to develop more complex programs.



"Hello Numeric, I'm a string. I store a chain of characters. You can easily recognize me—look at my antennas!"

The Two Types of Variables

There are two *types* of variables in BASIC: *numeric* and *string*. Numeric variables represent numbers; string variables represent text. These two types of variables look different; a string variable has a "$" at the end of the name. They are also used differently. For example, you can add numbers, but not text. Let's first learn about numeric variables, then about string variables.

Numeric Variables

Let's learn the rules for naming a numeric variable; then we will learn how to use these variables effectively. We have already used two numeric variables, called A and B, at the beginning of this chapter. We gave them a value by INPUTing numbers from the keyboard. Let's now learn how to name a variable.

When naming a variable, all BASICs, including the original Dartmouth BASIC, allow the use of one letter, optionally followed by a single number. Atari BASIC allows the use of one capital letter, optionally followed by other capital letters or numbers, up to 120 characters. Unlike some BASICs, it recognizes all 120 characters. Here are some examples of valid Atari BASIC variable names:

A	*(one letter)*
B	*(one letter)*
Z	*(one letter)*
A1	*(one letter and one digit)*
A2	*(one letter and one digit)*
B2	*(one letter and one digit)*

With this definition, the following names are not legal:

12 *(does not start with a letter)*

BA *(only one letter permitted)*

1B *(must start with a letter)*

The advantage of short names is to reduce the size and complexity of the BASIC interpreter. The disadvantage is that short names are difficult to remember. For example, the long name RESULT is more descriptive and memorable than the short name R. To improve readability, Atari BASIC allows long names, i.e., a sequence of characters. You may use any number of consecutive letters followed by optional digits, up to a maximum length of 120 characters. For example, the following are legal longer variable names:

WINNER	STUDENT1
LOSER	STUDENT2
RESULT	STUDENT14
SUM	CASE24

The following are not legal:

3TIMES *(starts with a digit)*

A-ONE *(illegal symbol)*

Every variable must have a name

Clearly a program with long, explicit variable names is more readable. In this chapter, we will use both short and long names, so that you can get used to both conventions. Remember that long names are simply a matter of convenience and will not affect the program in any way.

There is one more restriction on names: you cannot use a name that is a *reserved word*, i.e., a name that has a meaning to your BASIC interpreter. For example, you may not use LIST, END or RUN as variable names. (**Note:** a list of reserved words appears at the end of this book, as well as at the end of your *Atari BASIC reference manual.*) Atari BASIC also prohibits you from using a reserved word as the first part of a variable name. To be safe, it is best never to use a reserved word in any part of a variable name.

Now that we know how to create legal names for numeric variables, let's learn how to give a name to a piece of text known as a *string.*

"I'm a string variable.
I contain text.
My name ends with a $."

String Variables

First, let us introduce strings. Here are examples of strings:

"RESULT"

"THIS IS AN EXAMPLE"

"MY NAME IS JOHN"

"25 TIMES 4 = "

Note that a string is normally enclosed in quotes; otherwise, it could be confused with a variable name. A string may contain any sequence of characters, except the quotation symbol. On the Atari, the length of a string is limited to 32,767 characters.

Let us now introduce string variables. When the value stored in a variable is text (that is a string), rather than a number, the variable is called a *string variable.*

A string variable's name is just like a numeric variable's name, except that it must have a "$" at the end. Here are some valid short string variable names:

A$

R$

A1$

B5$

Since Atari BASIC allows long names, here are several more valid names:

ABRACADABRA$

NAME$

FIRST$

CITY$

UNIT25$

Recall that names like AND$ and LETTER$ are illegal because they contain the reserved words AND and LET, respectively.

Let's now illustrate the use of string variables, with a program that greets the user by name.

```
10  DIM FIRST$(10), LAST$(20)
20  PRINT "I AM HAL, THE COMPUTER."
30  PRINT "WHAT IS YOUR FIRST NAME";
40  INPUT FIRST$
50  PRINT "AND WHAT IS YOUR LAST NAME";
60  INPUT LAST$
70  PRINT "HELLO, "; FIRST$; " "; LAST$; "!"
80  PRINT "NOW I KNOW YOUR NAME!"
90  PRINT "I LIKE "; FIRST$; " AS A FIRST NAME."
100 END
```

Here is a sample run. Note that the characters you type appear here in boldface type.

```
I AM HAL, THE COMPUTER.
WHAT IS YOUR FIRST NAME? JOHN
AND WHAT IS YOUR LAST NAME? SULLIVAN
HELLO, JOHN SULLIVAN!
NOW I KNOW YOUR NAME!
I LIKE JOHN AS A FIRST NAME.
```

You can now communicate with your computer! Let's point out some of the basic features of this program. Let's start with line 10:

```
10  DIM FIRST$(10), LAST$(20)
```

Before you can use a string variable, you must tell your Atari BASIC interpreter how much memory space to set aside for that variable. We call this dimensioning the variable, and it is accomplished by using a DIM statement. When you dimension a string variable, you are telling your computer what the maximum length of the string will be. In Atari BASIC, you can dimension a string, that is 1 to 32767 characters in length.

In the above DIM statement, ten characters worth of memory have been set aside for the string variable FIRST$, and twenty for the string variable LAST$. As another example, let's assume that you have an unusually long first name, say "Alakazamaroo." You need 12 characters worth of memory for FIRST$, so you would write:

```
10  DIM FIRST$(12), LAST$(20)
```

In Atari BASIC, you must always remember to dimension string variables. It is best to do this at the beginning of your program. If you forget, your program will terminate with an error message the first time it encounters an undimensioned variable.

The next line is:

```
20  PRINT "WHAT IS YOUR FIRST NAME";
```

Note that this line is terminated with a semicolon. The semicolon means "display the next character immediately after this text." The result of statement 20 and your response to statement 30 is:

```
WHAT IS YOUR FIRST NAME? JOHN
```

If you had written:

```
20  PRINT "WHAT IS YOUR FIRST NAME"
```

with no semicolon at the end, the result would have been:

```
WHAT IS YOUR FIRST NAME
?JOHN
```

Naturally, you may choose either way. The format is a matter of preference. But remember, if you want the characters you type to appear on the same line as the preceding message, use a semicolon at the end of the PRINT statement. Otherwise, the next position on the screen will be the beginning of the following line.

Now that we know more about numeric and string variables, let's use them as we continue our dialogue with Hal, the computer. Let's add the following to our program:

```
90  PRINT "WHAT IS THE CURRENT YEAR (2 DIGITS)";
100 INPUT CURRENTYEAR
110 PRINT "WHICH YEAR WERE YOU BORN (2 DIGITS)";
120 INPUT YEARBORN
130 PRINT "DEAR  "; FIRST$;  ", THIS YEAR YOU ARE OR
      WILL BE ";  CURRENTYEAR - YEARBORN
140 END
```

Here is a sample dialogue. Again, the characters you type are shown in boldface type.

```
WHAT IS THE CURRENT YEAR (2 DIGITS)? 83
WHAT YEAR WERE YOU BORN (2 DIGITS)? 50
DEAR JOHN, THIS YEAR YOU ARE OR WILL BE 33
```

Let us examine the program in detail. The statement

```
90  PRINT "WHAT IS THE CURRENT YEAR (2 DIGITS)";
```

prints the obvious message. Again a semicolon is used so that the two digits will be displayed on the same line. In the next statement,

```
100  INPUT CURRENTYEAR
```

CURRENTYEAR is a numeric variable. The value 83 that you typed will be read into it. From now on, whenever the name CURRENTYEAR is used, the value 83 will be substituted automatically by the BASIC interpreter. This will happen in statement 130.

The statement

```
110  PRINT "WHICH YEAR WERE YOU BORN (2 DIGITS)";
```

is just like statement 90. Note the semicolon at the end. The statement

```
120  INPUT YEARBORN
```

is just like statement 100. YEARBORN is a new numeric variable. It will soon contain the value 50. In the next statement (130) we use this variable name. Note that the value 50 is substituted automatically by the interpreter. Let's examine this:

```
130  PRINT "DEAR  "; FIRST$; ",  THIS YEAR YOU ARE OR
       WILL BE "; CURRENTYEAR - YEARBORN
```

When this statement is executed, the following is displayed:

```
DEAR JOHN, THIS YEAR YOU ARE OR WILL BE 33.
```

Let's break this display down and examine it.

DEAR

(This is called a literal string. A literal string is a string that is part of a program statement.)

JOHN

(This is the string value that is read at the keyboard and stored in the string variable named FIRST$. It remains there as long as you don't use the NEW command or enter a new value into FIRST$.)

THIS YEAR YOU ARE OR WILL BE
(This is another literal string.)

33
(This is the result of: CURRENTYEAR – YEARBORN, i.e., 83 – 50 = 33.)

In typing and examining this program, you may already have developed some frustrations. For example, you may have wanted to enter actual dates, including the day and month, so that you can compute your age, as of today. However, this requires comparing today's month and day with that of the birthdate's. To do this, we must learn about a new BASIC statement, the

IF (condition) THEN (do)

statement. We'll discuss this statement in detail in Chapter 7. Another thing that you might want to do is to design the program so that it executes repeatedly (so that you don't need to type RUN every time). We'll learn how to do this in Chapter 6, when we discuss the GOTO statement.

Now that we are familiar with both numeric and string variables, let's learn how we can use them in a longer program—first, by assigning a value to a variable, then by using the counter technique.

Assigning a Value to a Variable

So far, the only way we have given a value to a variable has been with the INPUT statement. For example, when the following statement is executed:

```
20  INPUT A
```

you type in a value, such as 5.2 (followed by a ↵), and the value of A is then 5.2.

There is, however, another way to assign a value to A. This is called the *assignment* statement. Here is an example:

```
10  A = 5.2
```

This statement assigns the value 5.2 to A as part of the program, so that you do not have to supply it from the keyboard. You might also write:

```
10  B = 1
20  C = 2
30  A = B + C
```

As you can see, the value of A will be set at 2 + 1 = 3 when statement 30 is executed.

Let's now show the value of the assignment statement. We will examine two examples. In both examples, we will compute the sum and the average of two numbers. Here is our first program, without the assignment statement:

```
10  PRINT "GIVE ME TWO NUMBERS"
20  PRINT "I WILL COMPUTE THEIR SUM AND AVERAGE"
30  PRINT "FIRST NUMBER PLEASE:";
40  INPUT A
50  PRINT "SECOND NUMBER PLEASE:";
60  INPUT B
70  PRINT "THE SUM OF "; A; " AND "; B; " IS: "; A + B
80  PRINT "THEIR AVERAGE IS: "; (A + B)/2
90  END
```

And here is a typical run:

```
GIVE ME TWO NUMBERS
I WILL COMPUTE THEIR SUM AND AVERAGE
FIRST NUMBER PLEASE: 24
SECOND NUMBER PLEASE: 41
THE SUM OF 24 AND 41 IS: 65
THEIR AVERAGE IS: 32.5
```

Notice that the expression A + B is repeated twice in the PRINT statements. This is just a minor inconvenience. However, in a

longer program, this would increase the probability of typing errors. In addition, if we were to change the program to use a different formula, much rewriting would be needed.

Here is an equivalent program that uses an *intermediate variable,* called SUM, to store the result. It is easier to read, and less error prone.

```
10  PRINT "GIVE ME NUMBERS"
20  PRINT "I WILL COMPUTE THEIR SUM AND AVERAGE"
30  PRINT "FIRST NUMBER PLEASE:";
40  INPUT A
50  PRINT "SECOND NUMBER PLEASE:";
60  INPUT B
70  SUM = A + B
80  AVERAGE = SUM / 2
90  PRINT "THE SUM OF THE ABOVE NUMBERS IS: "; SUM
100 PRINT "THEIR AVERAGE IS: "; AVERAGE
110 END
```

Two new variables are used:

```
70  SUM = A + B
80  AVERAGE = SUM / 2
```

Using additional variable names has two advantages: the program is clearer, and it is easier to modify. For example, let's assume that we now want to modify this program to obtain the average of three numbers. To do this, we would type:

```
62  PRINT "THIRD NUMBER PLEASE:";
64  INPUT C
70  SUM = A + B + C
80  AVERAGE = SUM / 3
```

We would leave the rest of the program unchanged. We have simply read in a third number, and modified the formulas at a single location. Here is the complete program:

```
10  PRINT "GIVE ME NUMBERS"
20  PRINT "I WILL COMPUTE THEIR SUM AND AVERAGE"
30  PRINT "FIRST NUMBER PLEASE:";
40  INPUT A
50  PRINT "SECOND NUMBER PLEASE:";
60  INPUT B
62  PRINT "THIRD NUMBER PLEASE:";
64  INPUT C
70  SUM = A + B + C
80  AVERAGE = SUM / 3
90  PRINT "THE SUM OF THE ABOVE NUMBERS IS: "; SUM
100 PRINT "THEIR AVERAGE IS: "; AVERAGE
110 END
```

And a typical run:

```
GIVE ME NUMBERS
I WILL COMPUTE THEIR SUM AND AVERAGE
FIRST NUMBER PLEASE:? 5
SECOND NUMBER PLEASE:? 3
THIRD NUMBER PLEASE:? 10
THE SUM OF THE ABOVE NUMBERS IS: 18
THEIR AVERAGE IS: 6
```

We have now learned two methods for associating a value with a variable:

- We can use the INPUT statement—where a value is supplied at RUN time, i.e., when the program is executed.
- We can use the assignment statement—where a value or a method to compute the value (a formula) is stored within the program itself.

The first method (using the INPUT statement) should be used when you expect that the value explicitly supplied to the variable (that is, not a *computed* value) will be different every time the program is executed.

The second method (using the assignment statements) should be used whenever you are using a formula to compute the value of the variable, or whenever you expect the explicit value (i.e., not a *computed* value) to remain the same every time the program is executed.

Let's now learn the complete rules for writing an assignment statement.

The Syntax of an Assignment

The rules (or syntax) for writing an assignment statement are simple. The general form of an assignment statement is:

< variable> = < expression>

There must always be a variable on the left and an expression on the right. More precisely, an expression is:

- a number or a variable, or
- a number or a variable followed by an operator (such as +, −, *, /), and another expression.

Here are a few sample expressions:

3	*(a number)*
A	*(a variable)*

```
2 + 2          (number, operator, number)
A + 2          (variable, operator, number)
A + B * 3      (variable, operator, expression)
```

Expressions may be enclosed in parentheses, for example:

```
3 + (A + 2) / 2
B + ((C * 2) + (D / 2)) / 4
```

You may want to think of an expression as a value, or as something that will be computed and will result in a value (in other words, as a formula for computing a value).

The equal (=) sign used in an assignment statement is not interpreted the same as in standard mathematics. In an expression it means "receives the value of." For example, you may write:

```
10  A = 1
20  A = A + 1
```

(The expression A = A + 1 would be meaningless or absurd in ordinary mathematics.) In BASIC, after statement 20 is executed, the value of A will be 1 (the previous value of A) + 1 = 2. Remember that in an assignment statement in BASIC, the = sign means that the variable on the left receives the value of the expression on the right.

Here are examples of valid assignment statements:

```
A = -3 + 2    (-3 is a negative integer)
B = A + 1
C = (2 * 3) + (A / B)
AVERAGE = SUM / NUMBER
SQUARE = A ^ 2
X = B ^ 2 - (4 * A * C)
```

Let's examine this last assignment and verify that it satisfies our definition:

```
B ^ 2
```

is

<variable> <operator> <number>

followed by

```
- (4 * A * C)
```

i.e.,

<operator> <parenthesized expression counting as a value>

Inside the parentheses:

```
4 * A * C
```

is

<number> <operator> <variable> <operator> <variable>

Yes, it is a valid expression.

The following assignments, however, are not valid:

B + C = SUM	*(only one variable (not an expression) on the left of the = sign)*
2 = A	*(there must be a variable, not a value on the left)*
SUM = B + C (D / 3)	*(missing operator after C)*
(AVERAGE) = (B + C) / 2	*(no parentheses allowed on the left)*
A =	*(missing value on the right)*

Finally, note that at the time an assignment is executed, all variables on the right of the = sign must have received a value. If you write

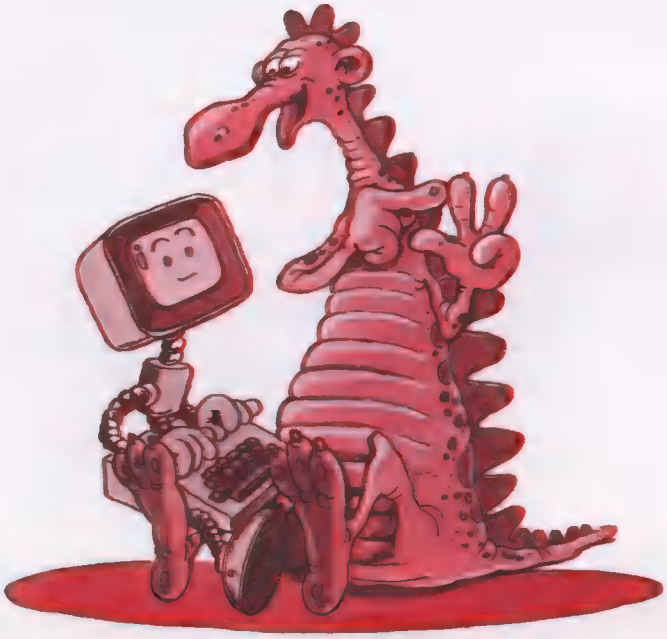
```
10 B = 2
20 SUM = B + C
30 INPUT C
```

the program will fail at line 20, since C does not have a value. You probably meant to write:

```
10 B = 2
20 INPUT C
30 SUM = B + C
```

We've now learned the syntax of assignments. Let's use this new skill and introduce an important technique that uses assignments: the *counting technique*. We will use it in many of our programs.

"Let's play counter!"



"I'm a counter variable."

The Variable Counter Technique

Remember that a variable is simply a name given to a memory location. A value can be stored in a memory location by using an INPUT statement or an assignment statement (=). In this example, we want to change the value of a variable repeatedly, in order to count events. The technique we will use to do this is called the *variable counter* technique.

Let's now demonstrate how successive assignments can change the value of the variable N. Type the following in the direct mode:

```
N = 1
```

The value is automatically stored in N. Let's verify that it is. Type:

```
PRINT N
```

The value 1 appears. Now type:

```
N = 2
```

N now contains 2. Type:

```
PRINT N
```

The response is:

```
 2
```

The value 2 has been substituted for the value 1 in N. Type:

```
N = 3
```

Now type:

```
PRINT N
```

and verify that the value 3 has been stored in N. The mechanism works. We will soon use this technique to count events. In other words, a variable can be used as an event counter. Here is a preview of an advanced program that counts how many times you supply a number at the keyboard. It stops when you hit zero.

```
10  SUM = 0
20  SUM = SUM + 1
30  PRINT "ENTER ANY NUMBER. TYPE 0 TO STOP";
40  INPUT NUMBER
50  PRINT "YOU HAVE ENTERED "; SUM; " NUMBERS"
60  IF NUMBER< >0 THEN 20
70  END
```

Later on in Chapter 6, we will examine statements like statement 60 in greater detail. The statement means: IF NUMBER is not

equal to (< >) zero, THEN execute statement 20. Here is a typical run:

```
ENTER ANY NUMBER. TYPE 0 TO STOP? 5
YOU HAVE ENTERED 1 NUMBERS
ENTER ANY NUMBER. TYPE 0 TO STOP? 1
YOU HAVE ENTERED 2 NUMBERS
ENTER ANY NUMBER. TYPE 0 TO STOP? 2
YOU HAVE ENTERED 3 NUMBERS
ENTER ANY NUMBER. TYPE 0 TO STOP? 3
YOU HAVE ENTERED 4 NUMBERS
ENTER ANY NUMBER. TYPE 0 TO STOP? 4
YOU HAVE ENTERED 5 NUMBERS
ENTER ANY NUMBER. TYPE 0 TO STOP? 0
YOU HAVE ENTERED 6 NUMBERS
```

In this program, the value of SUM is *initialized* to 0 in the first statement. It increases by one every time a new number is entered. This is a counter variable. We will see many examples of this technique as we write more programs. Later, we will learn how to tune up such a program, if we don't want to have 0 count as a number when we stop the program.

Summary

In this chapter we have learned to write programs that can be used repeatedly. These programs will supply new results depending on values provided at the keyboard. We have achieved this by using variables and assigning values to them in various ways.

A variable should be thought of as a name given to a memory location in which a value or text may be stored or accumulated.

We have learned to change the contents of a variable by using an INPUT or assignment statement. We can now write a simple program that automates a dialogue or a simple computation.

However, our programs now consistently exceed ten lines. They have become long. Let's keep them clear. In the next chapter, before proceeding any further and learning new tools and techniques, we will learn how to write a clear program.

Exercises

4-1: Read four numbers at the keyboard and display the total, the average, and the product of the four numbers.

4-2: Are the following variable names valid?

a. 24B	e. ALPHA2D	i. PI
b. B24	f. EXAMPLE	j. 3$
c. A+B	g. INPUT	k. THREE
d. APLUSB	h. INPUT1	l. NAME$

4-3: Write a program that asks the name of the user and says: "I THINK I KNOW A (name here)!"

4-4: Write a program that requests:

— the name of an object

— the name of a piece of furniture

— the name of a friend

then says: "DOES YOUR FRIEND (name) HAVE A (object) ON A (piece of furniture)?"

4-5: Write a program that requests the color of your eyes, then says: "I LIKE (color) EYES."

4-6: Are the following assignments valid?

a. A + 1 = A	d. B + C = A
b. A = A + A + A	e. 3 = 2 + 1
c. A = B + C	f. NUMBER = FIRST + LAST * 2

Writing a Cl

5

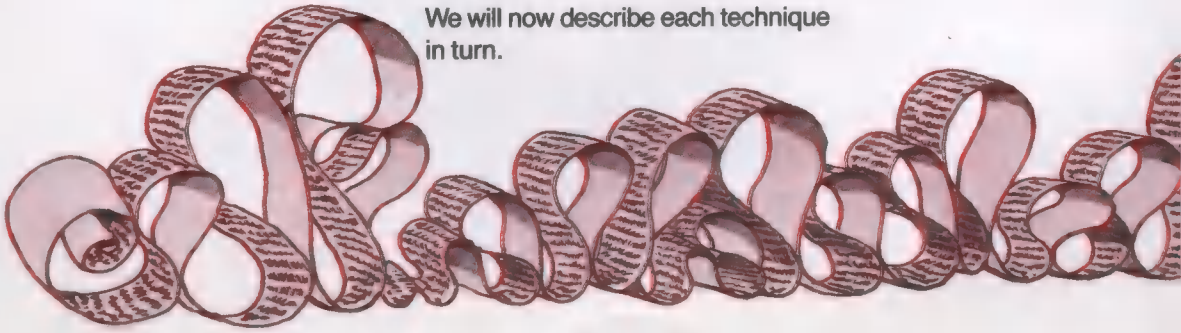
So far, we have written short programs using three different types of statements: PRINT, INPUT, and assignment (=). We have also learned how to write simple arithmetic expressions. In the chapters that follow, we will learn new techniques and statement types, and we will write longer programs. Before we proceed, however, let's learn to make our programs clear and readable.

Making a program readable is important. If you write a program today and wish to use it or change it in a few days, it will probably take you some time to remember and understand what the program does, and how. As a rule, plan in advance and make each program as readable as possible as soon as you write it. The purpose of this chapter is to help you improve your program readability.

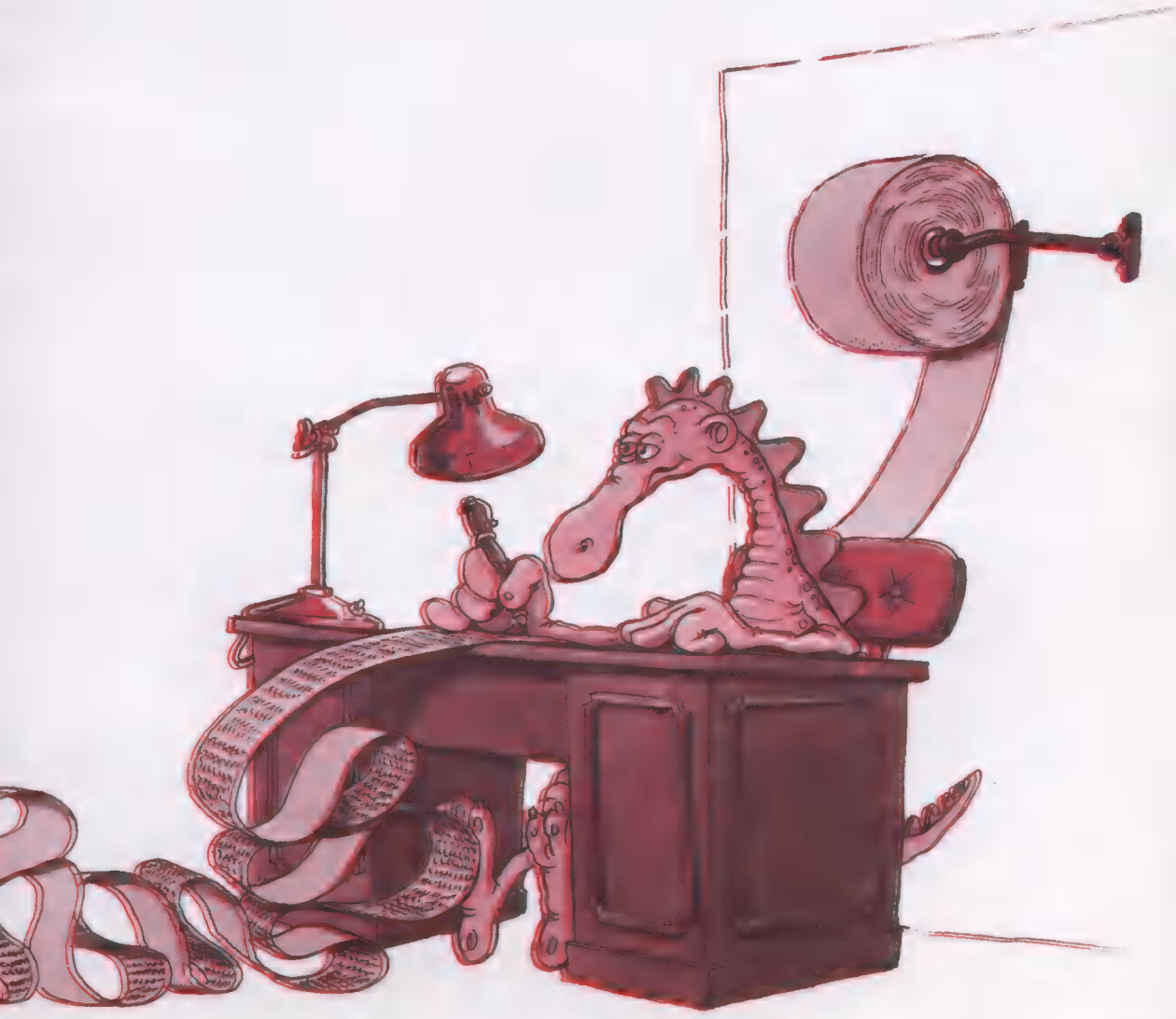
We will examine seven techniques:

1. The use of the REM statement (to introduce *remarks* in a program)
2. The use of multiple statements on one line
3. The use of blanks within a statement
4. The use of the statement that clears the screen and the "empty PRINT" statement (to improve the display on the screen)
5. The use of the "shortcut INPUT" statement (to reduce the number of lines in a program)
6. The selection of meaningful names for variables
7. The proper line numbering.

We will now describe each technique in turn.



ear Program



The REM Statement

Here is an example using the REM statement:

```
10  REM * * * ADDITION PROGRAM * * *
20  PRINT "GIVE ME TWO NUMBERS: ";
30  INPUT FIRST, LAST
40  PRINT "THEIR SUM IS:  ";  FIRST + LAST
50  END
```

The REM statement is used to make the program more readable by introducing comments in the text. This statement is ignored by the interpreter when the program is executed and has no effect on the program. Here are additional examples of remarks you could use:

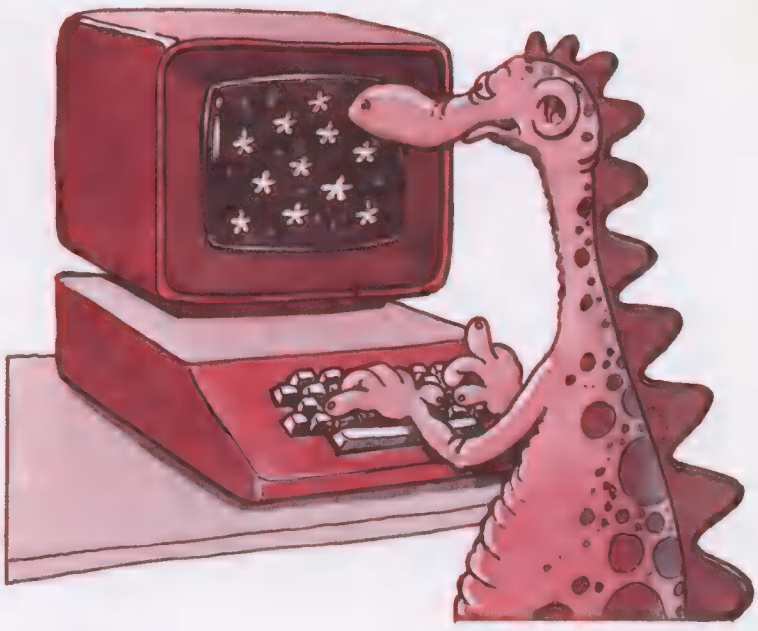
```
25  REM NOW READ THE TWO NUMBERS
45  REM WE COULD ALSO MULTIPLY THEM AS PART OF THE
      ABOVE STATEMENT
```

and here is the resulting program

```
10  REM * * * ADDITION PROGRAM * * *
20  PRINT "GIVE ME TWO NUMBERS:  ";
25  REM NOW READ THE TWO NUMBERS
30  INPUT FIRST, LAST
40  PRINT "THEIR SUM IS:  ";  FIRST + LAST
45  REM WE COULD ALSO MULTIPLY THEM AS PART OF
    THE ABOVE STATEMENT
50  END
```

REMarks are invisible to the interpreter

"See how a few stars make my program more readable."



For improved readability, you may want to use stars, dashes or other symbols:

```
10   REM *** ADDITION PROGRAM ***
60   REM-----SECOND PART-----
100  REM =====GRAND FINALE=====
200  REM $$$$$CHANGE THIS SECTION LATER$$$$$
```

Multiple Statements on a Line

Atari BASIC allows you to write two or more statements on the same line, separated by a colon. Here is an example:

```
50  PRINT "TYPE NUMBER";  :  INPUT NUMBER
```

This is equivalent to:

```
50  PRINT "TYPE NUMBER";
60  INPUT NUMBER
```

Note that there can be only one line number per line. Therefore, when two statements are written on the same line, there is only one line number on the left. Here is another example:

```
100  REM *** COMPUTE EVERYTHING ON ONE LINE ***
110  SUM = A + B  :  PRODUCT = A * B  :  AVERAGE = SUM/2
```

There are three statements on line 110.

Writing multiple statements on the same line is beneficial in at least two cases: to clarify an INPUT and to introduce a REMark to the right of the statement. Here is an example showing how the INPUT is clarified:

```
70  PRINT "ENTER 2 NUMBERS";  :  INPUT N1, N2
```

Line 70 is written to correspond to what happens on the screen. This makes the program easier to read.

Here is an example showing how a REMark is introduced on the same line as the statement it refers to:

```
60  RESULT = A + 2 * B - 5  :  REM THE RESULT MUST BE POSITIVE
```

Here is another one:

```
50  TEMPERATURE = (FAHR - 32) * 5/9  :  REM WE CONVERT
      TO CELSIUS
```

Using Blanks

With the exception of names, strings, or input data, blanks are generally ignored by BASIC. For example, you may write:

```
20 PRINT4+2*3
```

However, a statement like this is hard to read. To facilitate reading back your program, use blanks liberally. Use blanks:

- *after each reserved word, such as PRINT and INPUT.*

Here are examples:

```
50  PRINT  4
60  INPUT NUMBER
```

- *before and after each operator.*

Here are examples:

```
30  PRINT  4  +  2  *  3
40  RESULT  =  A1 / ((B  -  C)  *  D)
```

You may also want to use blanks before a reserved word, to align or indent statements in your program. Here is an example:

```
10   PRINT "TEN"
20   PRINT "TWENTY"
90   PRINT "NINETY"
100  PRINT "ONE HUNDRED"
200  PRINT "TWO HUNDRED"
```

Use blanks liberally

Without the two leading blanks in lines 10, 20, and 90, the program would look like this:

```
10 PRINT "TEN"
20 PRINT "TWENTY"
90 PRINT "NINETY"
100 PRINT "ONE HUNDRED"
200 PRINT "TWO HUNDRED"
```

Finally, here is an example of using blanks within a REM statement to even further facilitate reading:

```
1 REM  THIS PROGRAM MAINTAINS MY INVENTORY
2 REM  COPYRIGHT MYSELF 1982
3 REM  THESE ARE THE VARIABLES:
4 REM  C    IS THE COLOR (1 TO 10)
5 REM  U    IS THE NUMBER OF UNITS (UP TO 1000)
6 REM  S    IS THE SIZE (1 TO 50)
7 REM  CST  IS THE UNIT COST
8 REM  R    IS THE RETAIL PRICE
9 REM  Q    IS THE REORDER QUANTITIES
```

Note how the blanks are used to enhance readability. You may not, however, add blanks in the middle of a reserved word, a variable name, or during a response to INPUT, unless the blanks are part of a string.

Improving the Display

Two new techniques can be used to improve the way your results look on the screen: the statement that clears the screen and the empty PRINT statement.

There may be times when you will want to clear the screen before your program begins displaying information. We already know how to accomplish this in the direct mode—you depress SHIFT and CLEAR. To clear the screen within a program, you must also use the ESC (escape) key. Let's say you wanted to clear the screen at the very beginning of your program. Assuming line 10 is your first program line, you would type:

```
10 PRINT " [ESC] [SHIFT] [CLEAR] "
```

The empty PRINT statement can be used to display a blank line. You simply type:

```
50 PRINT
```

and a blank line will be displayed. If you want to skip three lines on the screen, type:

```
50 PRINT : PRINT : PRINT
```

Or, equivalently:

```
50 PRINT
60 PRINT
70 PRINT
```

Shortcut INPUT

Everytime you use an INPUT statement, you should prompt the user of the program by explaining what to enter. Here is an example:

```
50 PRINT "TYPE TWO INTEGERS";
60 INPUT AGE1, AGE2
```

Keep it simple!

The sequence PRINT-INPUT is used so often that Atari BASIC allows a shortcut statement which saves you from having to type in two separate program lines; for example you may type:

```
50 PRINT "TYPE TWO INTEGERS";:INPUT AGE1, AGE2
```

This shortcut technique reduces the amount of typing required and shows clearly what will be displayed on the screen.

Selecting Variable Names

You should always select variable names so that you can easily remember what the name represents. Otherwise, you may find it difficult to write a long program, and you may make many accidental errors. Also, if your variable names are not clear, you may find that at a later date you are unable to figure out what your program does.

Atari BASIC allows multiple letter names, so use them. Here is an example showing the use of variable names that are easy to remember:

```
10 REM HERE ARE THE VARIABLES FOR THE SECOND NUMBER
20 REM      RESULT      FOR THE RESULT
30 REM      FIRST       FOR THE FIRST NUMBER
40 REM      LAST        FOR THE LAST NUMBER
```

Two main restrictions apply:

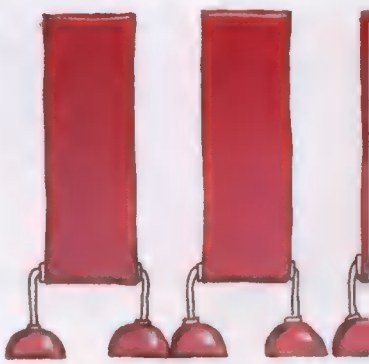
- Atari BASIC restricts you to a maximum of 120 characters.
- You may not use a reserved word, such as PRINT, REM or INPUT, as a variable name.

It is a good idea to identify all your variable names at the beginning of each program, as well as any formulas or equations you will be using.

Proper Line Numbering

So far in this chapter we have numbered lines by multiples of 10:

```
10 (statement)
20 (statement)
30 (statement)
```



You may, however, use any sequence you want, as long as you use positive integers, and you do not go over 32767, your interpreter's limit for line numbers. For example, you may write:

```
1  (statement)
2  (statement)
3  (statement)
```

or:

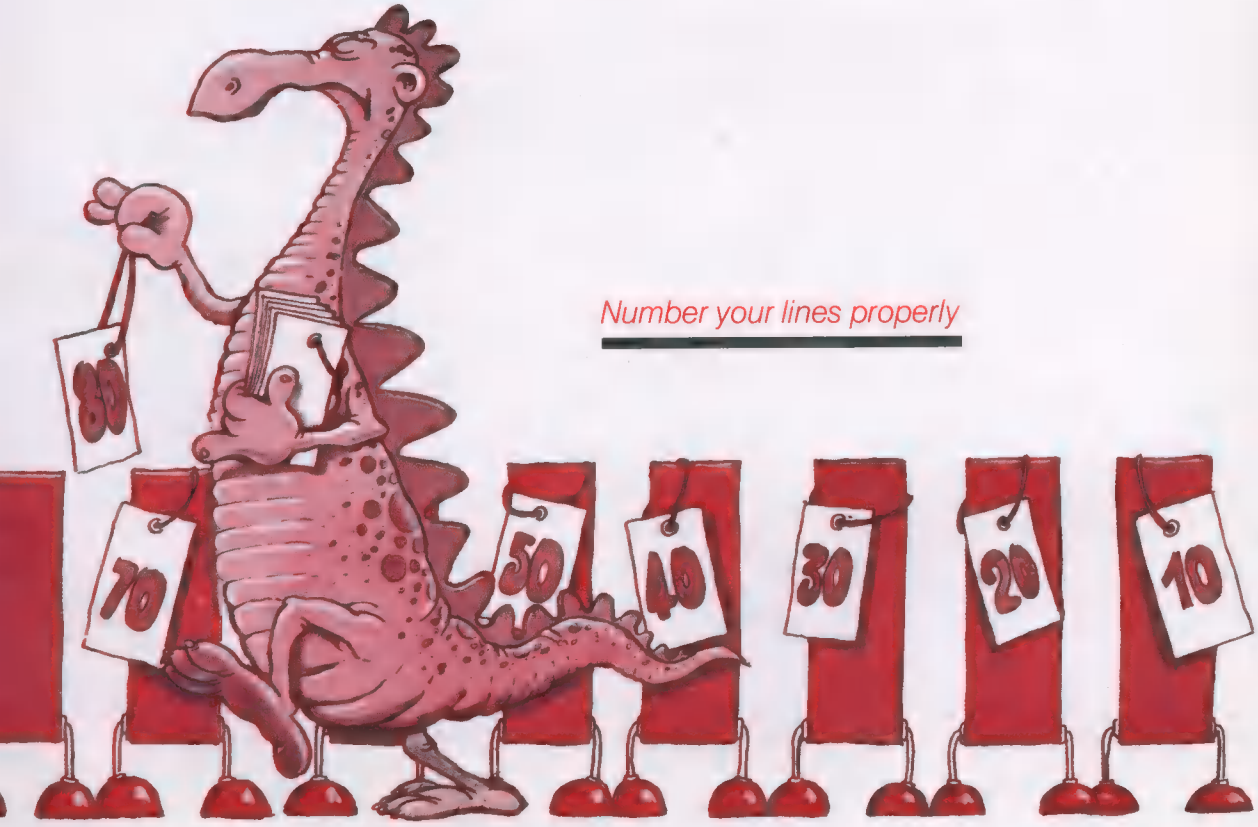
```
100  (statement)
200  (statement)
300  (statement)
```

We have taken the precaution to leave a regular gap between consecutive statement numbers so that we can easily add corrections or improvements later on. For example, here is version 1 of a program:

```
10  REM * * * MULTIPLICATION PROGRAM * * *
20  PRINT "GIVE ME 2 NUMBERS"; : INPUT N1, N2
30  PRINT "THE PRODUCT IS: "; N1 * N2
40  END
```

We now want to clarify the program and improve the display. To do this, we will type the following additional statements:

```
15  PRINT "THIS IS AN AUTOMATIC MULTIPLICATION PROGRAM"
16  PRINT  :  PRINT  :  PRINT
35  PRINT  :  PRINT
```



Number your lines properly

The new statements will be inserted automatically. Let's now list the result:

```
10  REM * * * MULTIPLICATION PROGRAM * * *
15  PRINT "THIS IS AN AUTOMATIC MULTIPLICATION PROGRAM"
16  PRINT  :  PRINT  :  PRINT
20  PRINT "GIVE ME 2 NUMBERS"; : INPUT N1, N2
30  PRINT "THE PRODUCT IS: "; N1 * N2
35  PRINT  :  PRINT
40  END
```

Here is a sample run of our improved program:

```
GIVE ME 2 NUMBERS? 12,15
THE PRODUCT IS: 180
```

If you plan to make many corrections, or add many statements, you may want to leave large gaps in your line numbering, and use for instance:

```
10   (statement)
50   (statement)
60   (statement)
100  (statement)
```

Summary

Writing programs that work involves one key ingredient: discipline. It is important to be as orderly and organized as possible when writing programs. Shortcuts increase the probability of mistakes. In particular, take the time to clarify your programs and your displays. In this chapter we have described and stressed the techniques necessary to write clear programs.

As you write programs in BASIC, you should make every effort to follow the suggestions offered in this chapter. It is essential that you acquire good programming habits, or else your programs may be unreadable, or may not even work, as you begin writing more and more complex programs.

Exercises

5-1: Describe techniques that improve the readability of the display.

5-2: Are the following legal?

a. A = A + 1

b. A = A + 1

c. PRINT ALPHA+2

d. SUM=2 + (3 + (4/5))/2

e. IN PUT NUMBER

f. SUM= 2 2 + 3 3

5-3: Explain why most INPUTs should have a prior message.

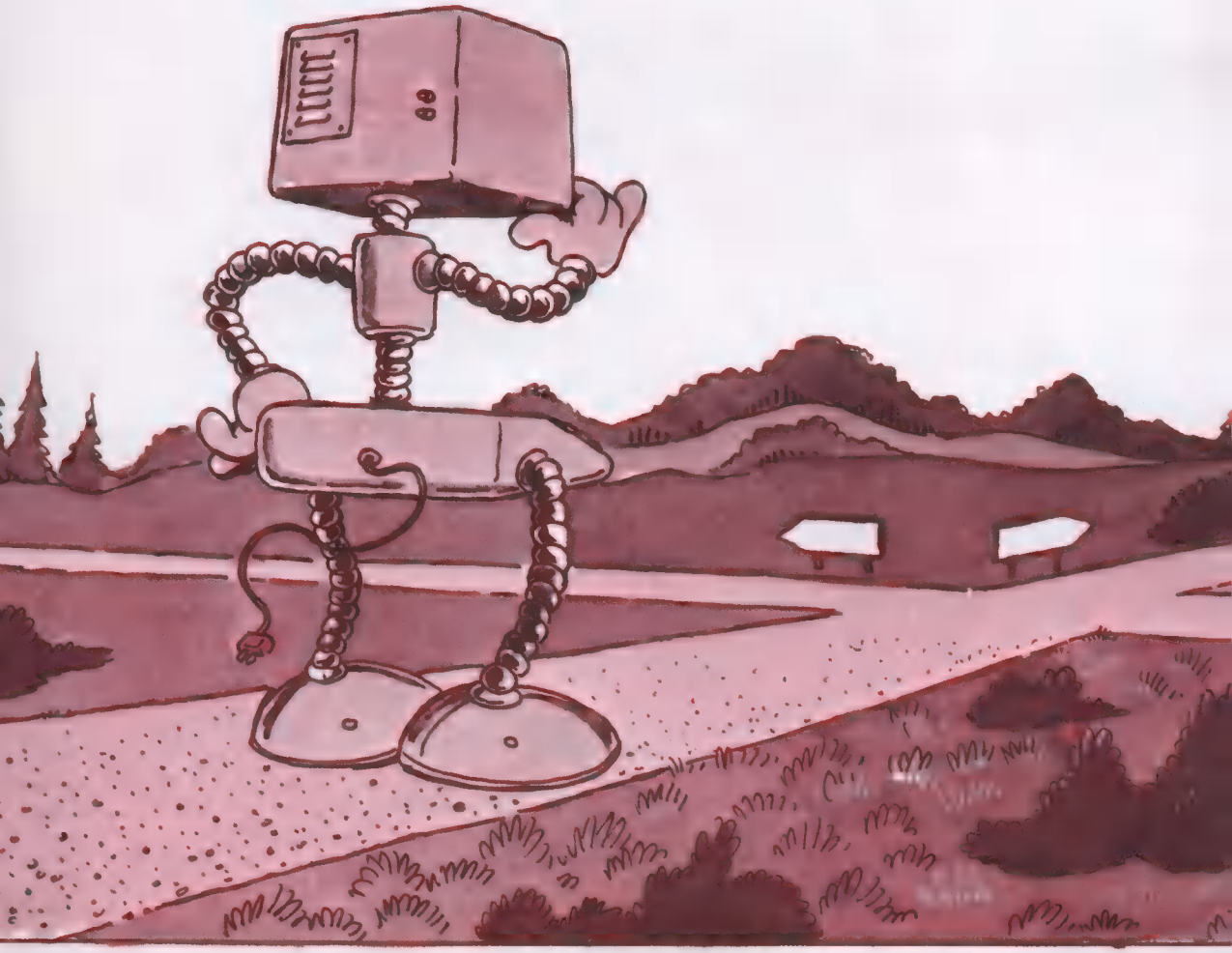
5-4: Write three examples of shortcut INPUTs.

5-5: Why use REMs?

5-6: What is the value of A after these two statements:

```
30  A = 3
40  REM A = 4
```

Making D



Decisions

6

So far, we have learned how to communicate with the computer and how to perform simple arithmetic. However, our programs have been somewhat dull, and we could easily have performed the same tasks by hand. This is because we have used only the elementary resources of the computer. We have not taken advantage of the more advanced resources. For example, computers are particularly good at performing two tasks: making complex decisions (based on logic and values) and executing repetitive tasks many times in a short period of time. This is what we will learn to do in this and the following chapter. In particular, we will learn how to make decisions. Our programs will become "intelligent," as they decide what to do.

In BASIC, program decisions are made by testing a value, using the IF statement. If the test succeeds, one part of the program is executed. If it fails, another part is executed. We will now learn how to use the IF statement to perform tests. We will also learn to use the GOTO statement to force the program to execute a group of instructions out of numerical sequence.

The IF Statement

The IF statement is written:

IF (condition) THEN (statement, i.e., do something)

Here is an example:

```
IF I = 1 THEN PRINT "ONE"
```

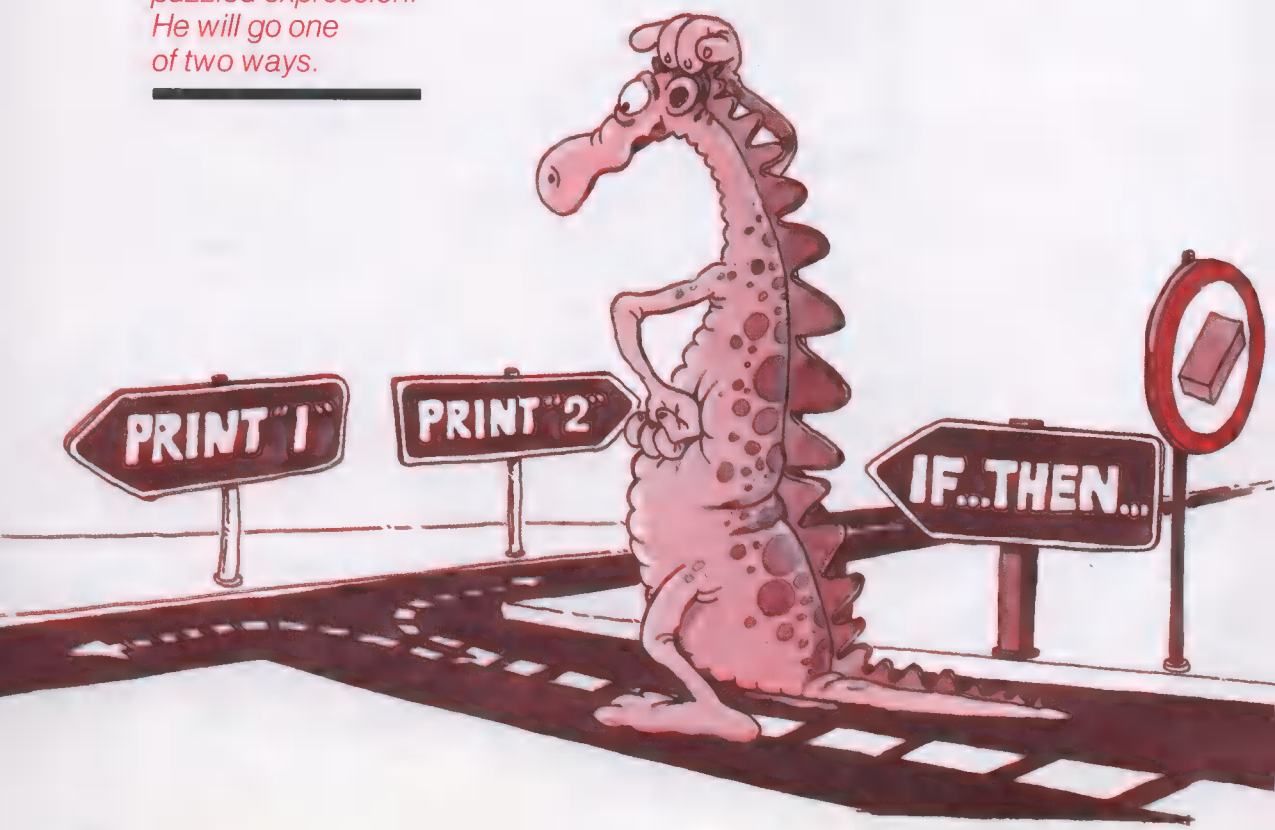
The effect of this statement should be clear: IF the value of the variable I is equal to 1 at the time this statement is executed, THEN the word ONE is printed. If I is not equal to 1, nothing happens and the next statement in the program is executed.

I = 1 is called a logical *expression*. The expression I = 1 is *true* when I is equal to 1; otherwise, it is *false*.

The IF . . . THEN statement allows you to test the value of an expression and execute one statement or another—that is, to make a decision—depending on the results of the test. Here is another example:

```
10  INPUT I
20  IF I = 1 THEN PRINT "ONE"
30  END
```

Look at Dino's puzzled expression. He will go one of two ways.



Now run this program. Type "1" at the keyboard. Your screen should look like this:

```
RUN
? 1
ONE

READY
■
```

Run this program again. Type "2" at the keyboard. Your screen should look like this:

```
RUN
? 2

READY
■
```

This time no message was printed in response to the 2.

Let's now teach our program to recognize the numbers 1 through 4:

```
10  REM THIS PROGRAM RECOGNIZES THE NUMBERS 1 TO 4
20  PRINT "TYPE AN INTEGER:"; : INPUT NUMBER
30  IF NUMBER = 1 THEN PRINT "ONE"
40  IF NUMBER = 2 THEN PRINT "TWO"
50  IF NUMBER = 3 THEN PRINT "THREE"
60  IF NUMBER = 4 THEN PRINT "FOUR"
70  END
```

Let's run the program. Here are two typical runs as they appear on the screen (with emphasis added):

```
RUN
TYPE AN INTEGER:? 3
THREE

READY
RUN
TYPE AN INTEGER:? 5

READY
■
```

This is good, but not yet perfect. Ideally, when we type 5, we would like the program to respond with something like:

```
I DON'T KNOW THIS NUMBER.
```

or else request a new integer.

There is a special feature of the IF statement that can make this happen. For example, you may write:

```
70  IF NUMBER = 5 THEN 20
```

where 20 is the number of the line to be executed if the test is successful. This is a new form of the IF statement. This statement means that if NUMBER is equal to five, then execute line number 20 next. We can now jump out of sequence! Here is an example:

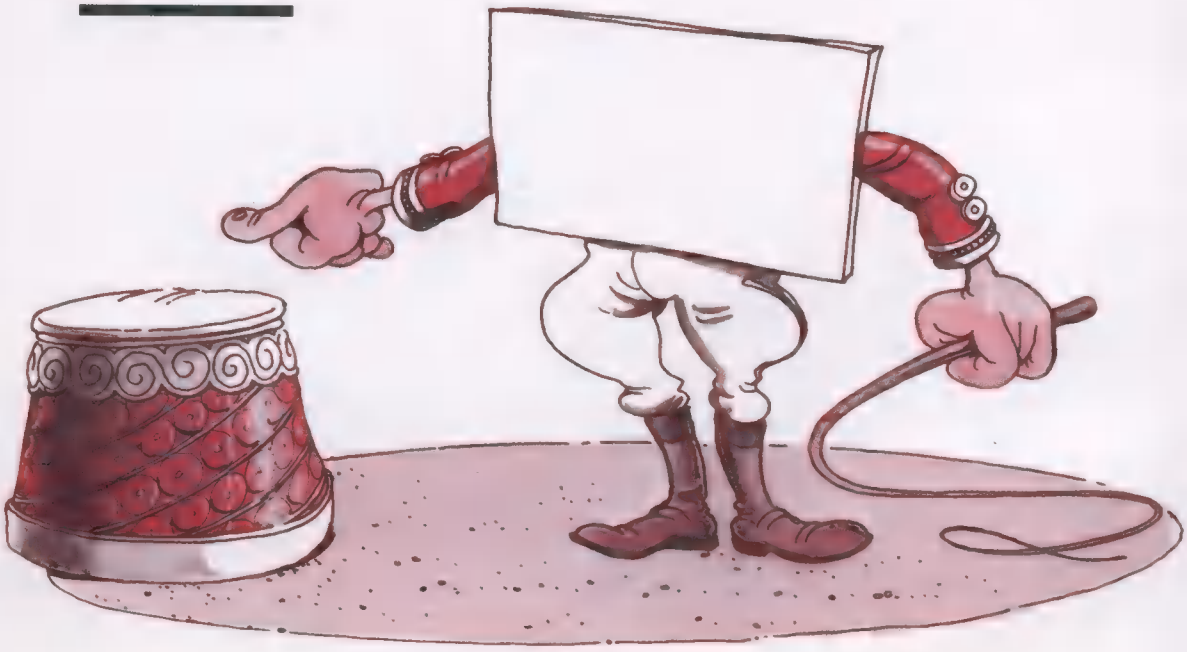
```
10  INPUT I
20  IF I = 1 THEN 50
30  PRINT "YOU DID NOT TYPE A 1"
40  END
50  PRINT "YOU TYPED A 1"
60  END
```

Run this program and type "1" at the keyboard. Your screen should look like this:

```
RUN
? 1
YOU TYPED A 1

READY
■
```

We can make the program jump out of sequence



Run the program again, and type a "2" at the keyboard. Your screen should look like this:

```
RUN
? 2
YOU DID NOT TYPE A 1

READY
■
```

Our program has become "intelligent," i.e., it gives an appropriate message whether or not the input is 1. You may be wondering if we could have achieved the same result using the original form of the IF statement. Let's try it:

```
10  INPUT I
20  IF I = 1 THEN PRINT "THIS IS A ONE"
30  PRINT "THIS IS NOT A ONE"
40  END
```

Now, run this program and type a 1 at the keyboard. The display is the following:

I'm the bug.
I got you.

```
RUN
? 1
THIS IS A ONE
THIS IS NOT A ONE

READY
■
```

It does not work. Regardless of the success or failure of the IF, the next statement following it in the program (statement 30 here) is executed.

In this example, we first get the correct message as the IF is executed:

```
THIS IS A ONE
```

Then the second message is printed anyway:

```
THIS IS NOT A ONE
```

The new form of the IF statement:

```
IF I = 1 THEN 50
```

eliminates this problem. We will use this statement frequently in our programs.

A successful IF forces the Interpreter to activate the instruction

Let's now take a closer look at the IF statement so that we can fully utilize it. The general form of the IF . . . THEN statement is the following:

IF (logical expression) THEN (executable statement or line number)

Let's now examine logical expressions and executable statements in turn.

Logical Expressions

In our example, I = 1 is a *logical expression*, i.e., it can be either *true* or *false*. True and false are called *logical values*. Here are some examples of logical expressions:

I = 1	*(I equals 1)*
I > 4	*(I is greater than 4)*
NUMBER < 100	*(NUMBER is less than 100)*
YEAR <> 5	*(YEAR is not equal to 5)*
AGE < 13	*(AGE is less than 13)*

A logical expression combines values or variables with logical operators. For completeness, the operators you can use with logical expressions are:

=	equal	
<>	not equal	*(in mathematics, this is written as ≠ or #)*
<	less than	
>	greater than	
<=	less than or equal	*(in mathematics, this is written as ≤)*
>=	greater than or equal	*(in mathematics, this is written as ≥)*

Here are some even more complex logical expressions:

```
(NUMBER + 2) > 4
(AGE - 5) >= 10
((2 * I - 5) / 2) < 10
2 > I
```

You may also write:

4 > 2	*(this is always true)*
4 = 2	*(this is always false)*

The following are *not* valid logical expressions:

2 < I < 0	*(only one relational operator may be used)*
(2 AGE - 2) < 5	*(invalid expression—missing an *. This should read: (2 * AGE - 2) < 5)*

You may even combine logical expressions using the *logical operators* AND, OR, and NOT. For example, you may write:

```
IF (AGE > 12) AND (AGE < 20) THEN PRINT "THIS IS A
  TEENAGER"
```

This statement will print "THIS IS A TEENAGER" whenever AGE is greater than 12 and less than 20. The AND is satisfied, i.e., true, when *both* of its clauses are true. Note, that you may *not* write:

```
IF AGE (> 12 AND < 20) THEN . . .
```

as each pair of parentheses must enclose a valid expression.

Here is another example using two logical expressions:

```
10  DIM ANSWER$(10)
20  INPUT ANSWER$
30  IF (ANSWER$ = "YES") OR (ANSWER$ = "NO") THEN 60
40  PRINT "INVALID ANSWER"
    . . .
60  PRINT "VALID ANSWER - LET US PROCEED"
```

This program segment collects an answer in the variable ANSWER$. (Recall that the $ at the end of the name is used to denote a string variable, i.e., a collection of characters.) YES or NO are the only valid answers; this program checks for the validity of what you have typed.

If you type YES, then (ANSWER$ = "YES") is true, and the IF succeeds: statement 60 is executed next, and the program prints:

```
VALID ANSWER - LET US PROCEED
```

Similarly, if you type NO, the same occurs.

If you type anything else, you get a diagnostic:

```
INVALID ANSWER
```

An OR is satisfied, i.e., *true*, whenever at least one of its two clauses is true. The OR fails when both of its clauses are false.

Relational operators can be used on variables

For example, if you type "YA", then (ANSWER$ = "YES") fails, and the second clause of the OR is tried (ANSWER$ = "NO"). It fails, and the program displays the message:

```
INVALID ANSWER
```

Finally, NOT can be used to negate a condition. Here is an example of a complex IF statement:

```
IF ((AVERAGE < 3.5) AND (LASTEXAM < 3.0) AND NOT (VERBAL > 4.0))
  THEN PRINT "FAILED"
```

In this statement, we check for three conditions at once. We will not discuss such complex statements any further here, but you may want to experiment with them on your own.

Executable Statements

Let us recall the definition of the IF statement:

IF (logical expression) THEN (executable statement or line number)

Now that we are familiar with logical expressions, let's examine the right part of this definition:

THEN (executable statement or line number)

An executable statement is simply any statement that is executed. It may be an assignment, an INPUT, or a PRINT statement. It may not, however, be another IF statement, or a command, such as REM, NEW, or LIST.

Now that we understand the theory of the IF statement, let's put it into practice.

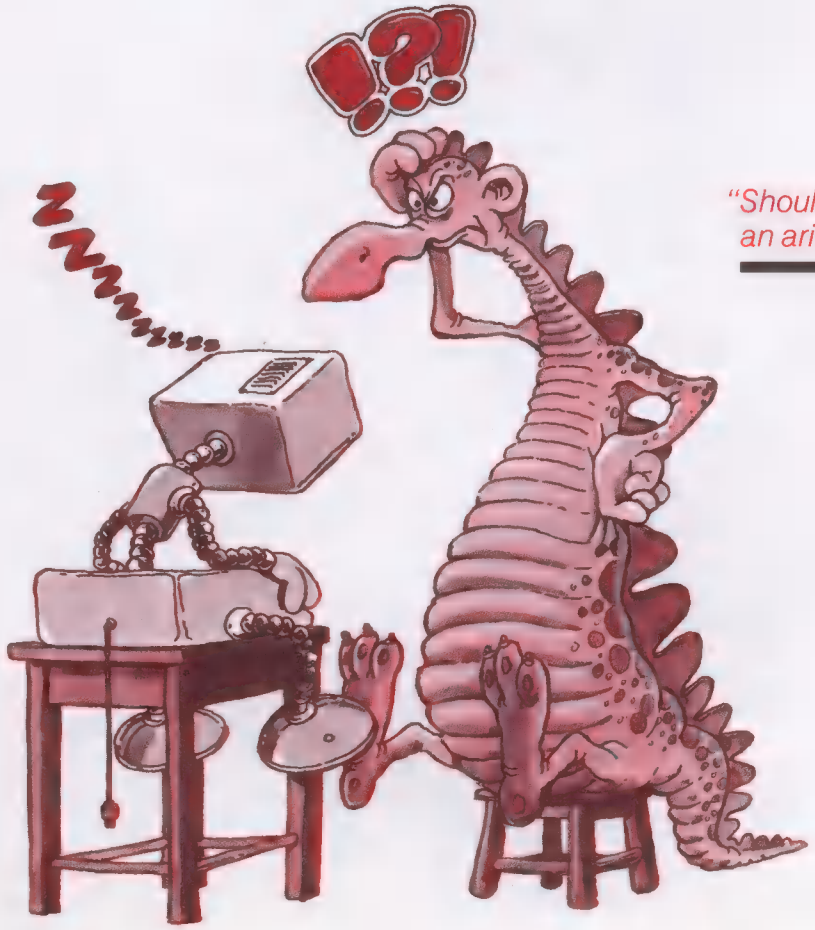
An Arithmetic Drill

Using our new skills, we will now develop a program that displays a "menu" on the screen. Depending on the user's selection, this educational program will perform additions, subtractions, multiplications, or divisions.

Here is the dialogue we plan to generate on the screen:

```
WELCOME TO COMPUTER TEACHER
I WILL CHECK YOUR ARITHMETIC SKILLS
WHAT DO YOU WANT TO PRACTICE?
    - ADDITION          (TYPE 1)
    - SUBTRACTION       (TYPE 2)
    - MULTIPLICATION    (TYPE 3)
    - DIVISION          (TYPE 4)
WHAT IS YOUR CHOICE (TYPE 1, 2, 3, OR 4)?: 3

ALL RIGHT. LET'S MULTIPLY.
HOW MUCH IS 2 TIMES 3: 6
THAT'S RIGHT. CONGRATULATIONS.
```



"Should I present an arithmetic menu?"

Now here is the program that accomplishes this:

```
10  REM * * THIS PROGRAM DRILLS YOU IN ARITHMETIC * *
20  PRINT "WELCOME TO COMPUTER TEACHER"
30  PRINT "I WILL CHECK YOUR ARITHMETIC SKILLS"
40  PRINT "WHAT DO YOU WANT TO PRACTICE?"
50  PRINT " - ADDITION          (TYPE 1)"
60  PRINT " - SUBTRACTION       (TYPE 2)"
70  PRINT " - MULTIPLICATION    (TYPE 3)"
80  PRINT " - DIVISION          (TYPE 4)"
90  PRINT "WHAT IS YOUR CHOICE: "; : INPUT CHOICE
100 IF (CHOICE = 1) THEN 200
110 IF (CHOICE = 2) THEN 300
120 IF (CHOICE = 3) THEN 400
130 IF (CHOICE = 4) THEN 500
140 PRINT "INCORRECT CHOICE. YOU MUST SELECT A NUMBER
      BETWEEN 1 AND 4"
150 PRINT "GOOD BYE"  :  END
190 REM - - - - - ADDITION - - - - -
200 PRINT "ALL RIGHT. LET'S ADD"
210 PRINT "HOW MUCH IS 4 + 7 :"; : INPUT NUMBER
220 IF (NUMBER< >11) THEN 600
230 PRINT "THAT'S RIGHT. CONGRATULATIONS" : END
290 REM - - - - - SUBTRACTION - - - - -
300 PRINT "ALL RIGHT. LET'S SUBTRACT"
310 PRINT "HOW MUCH IS 9 - 5  :"; : INPUT NUMBER
320 IF (NUMBER< >4) THEN 600
330 PRINT "THAT'S RIGHT. CONGRATULATIONS" : END
390 REM - - - - - MULTIPLICATION - - - - -
400 PRINT "ALL RIGHT. LET'S MULTIPLY"
410 PRINT "HOW MUCH IS 2 TIMES 3 :"; : INPUT NUMBER
420 IF (NUMBER< >6) THEN 600
430 PRINT "THAT'S RIGHT. CONGRATULATIONS" : END
490 REM - - - - - DIVISION - - - - -
500 PRINT "ALL RIGHT. LET'S DIVIDE"
510 PRINT "HOW MUCH IS 9 DIVIDED BY 3  :";  NUMBER
520 IF (NUMBER< >3) THEN 600
530 PRINT "THAT'S RIGHT. CONGRATULATIONS" : END
590 REM - - - - - FAILURE EXIT - - - - -
600 PRINT "WRONG. SORRY AND GOOD BYE." : END
```

This program looks imposing in size, but it is actually quite simple. Let's examine it.

Statements 20 to 90 produce the display or "menu" on the screen. The program checks the user's selection in statements 100 to 130 (the parentheses after each IF are not required; they are included for readability). If the user typed "1", then (CHOICE = 1) is true,

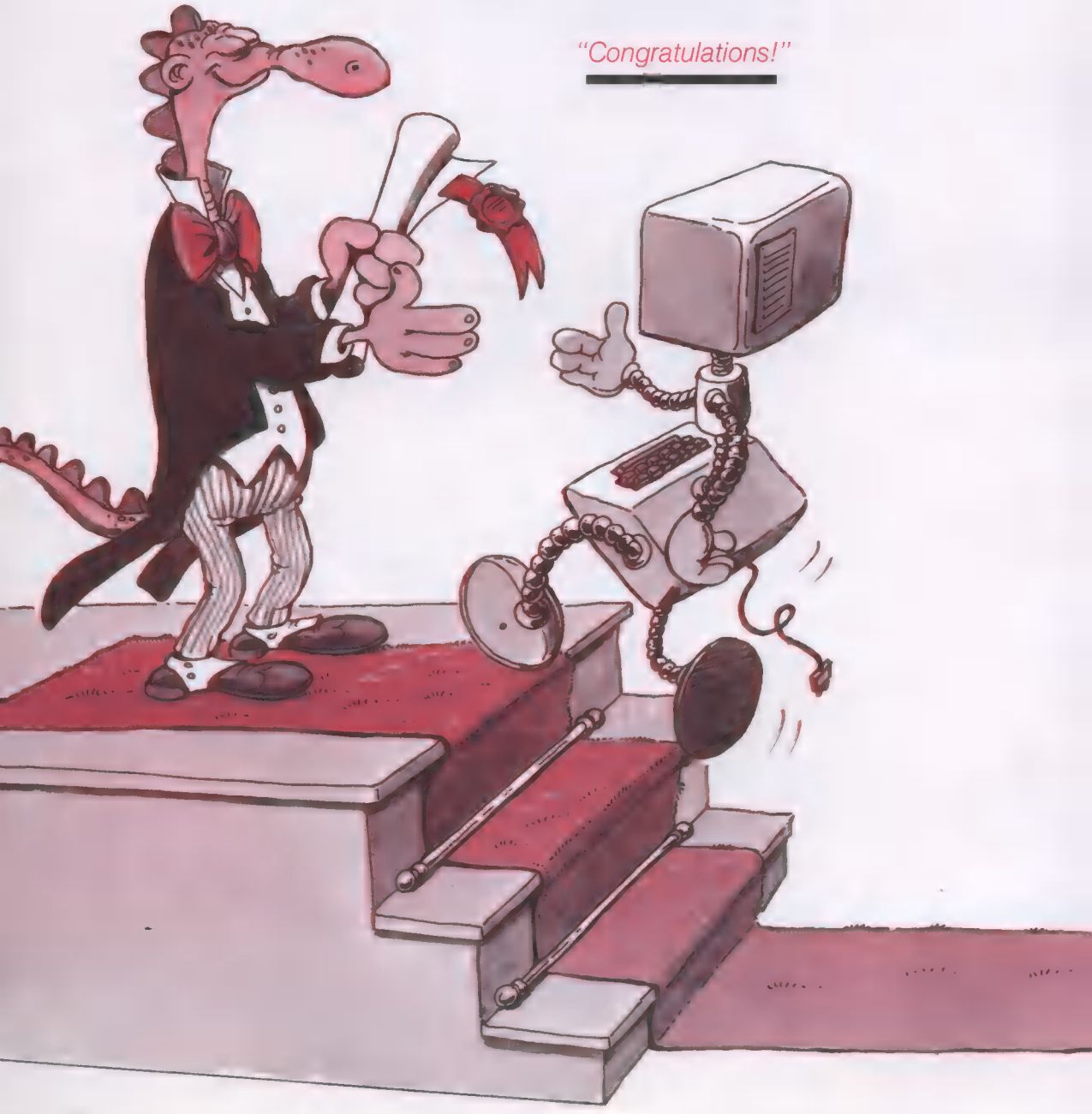
and statement 200 is executed next. If the user typed something other than 1, 2, 3, or 4, then statement 140 is executed and the program says:

```
   INCORRECT CHOICE. YOU MUST SELECT A
NUMBER BETWEEN 1 AND 4

GOODBYE
```

and quits (this is the : END statement on line 150).

In our example, we type 3. Statement 100 fails, so statement 110 is executed next. Statement 110 fails, so statement 120 is executed



next. Statement 120 succeeds, since (CHOICE = 3) is true, and statement 400 is executed next. Here is the corresponding program segment:

```
400  PRINT "ALL RIGHT. LET'S MULTIPLY"
410  PRINT "HOW MUCH IS 2 TIMES 3  :"; : INPUT NUMBER
420  IF (NUMBER< >6) THEN 600
430  PRINT "THAT'S RIGHT. CONGRATULATIONS" : END
```

In our example, we type 6 in response to statement 410. When statement 420 is executed, (NUMBER < > 6) is false since NUMBER = 6. (Recall that < > means not equal to.) Therefore, the next statement to be executed is statement 430, and the program responds with:

```
THAT'S RIGHT. CONGRATULATIONS

READY
■
```

and quits since line 430 contained *two* statements. The second statement is:

```
: END
```

Looking at this program, you may quickly spot a new frustration: If you type a number other than 1, 2, 3, or 4 after the menu is shown, or if you give an incorrect arithmetic answer, the program will stop abruptly. Ideally, we would like the program to continue. For example, it would be good if, after the program tells the user that a number other than 1 to 4 is not valid, it would then ask for a new choice. We would like to be able to go back to the beginning of the program and restart it, or more generally, to be able to go to *any* part of the program next. This is possible with the GOTO statement. Let us examine this statement.

The GOTO Statement

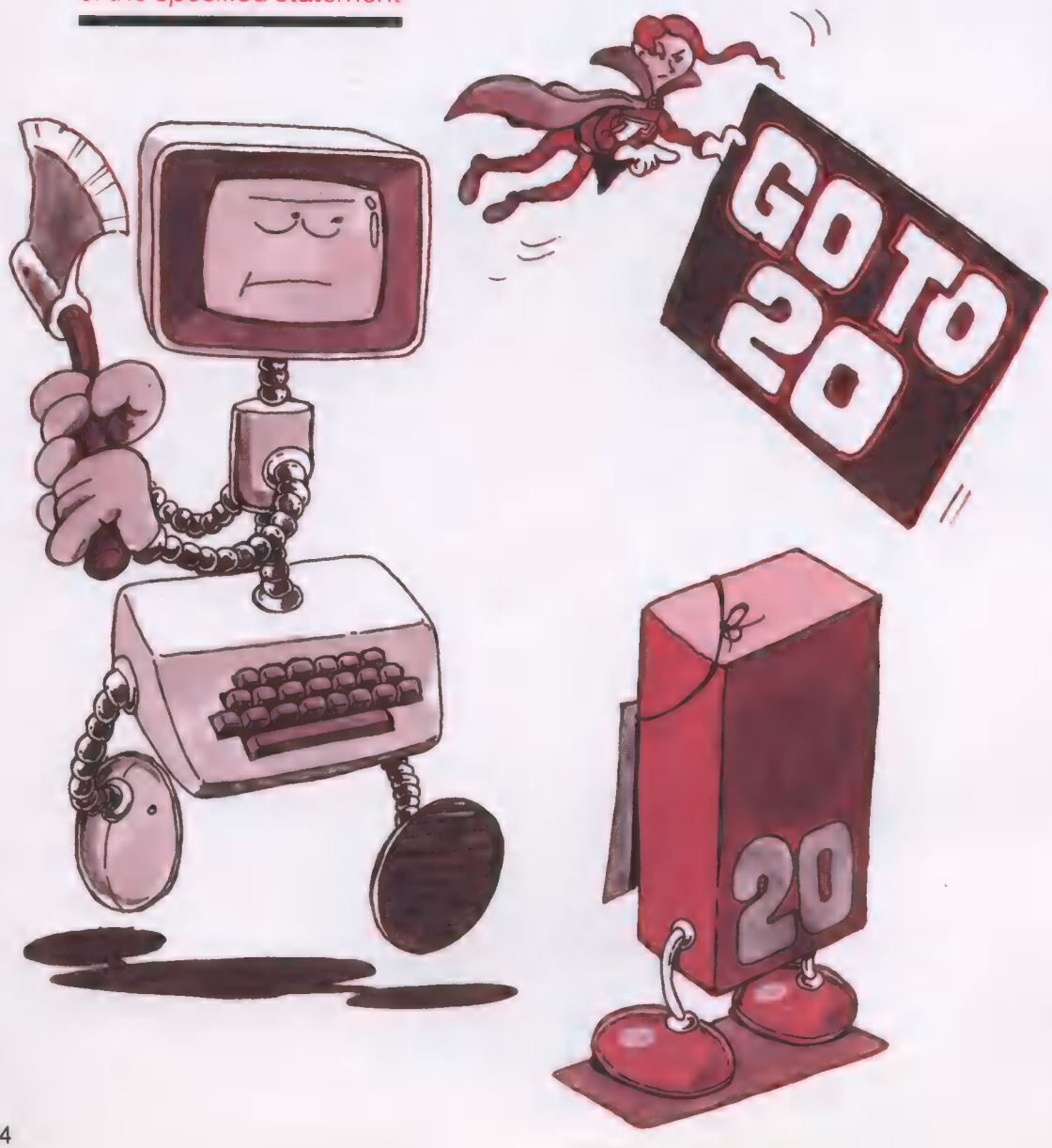
The GOTO statement is written as:

GOTO (line number)

It forces execution of the specified statement. Here is an example:

```
10  PRINT "THIS PROGRAM RECOGNIZES 1'S. TYPE 0 TO STOP."
20  PRINT "TYPE A NUMBER:"; : INPUT NUMBER
30  IF NUMBER = 1 THEN PRINT "ONE"
40  IF NUMBER = 0 THEN 60
50  GOTO 20
60  END
```

GOTO forces execution of the specified statement



Here is a sample run:

```
THIS PROGRAM RECOGNIZES 1'S. TYPE 0 TO
 STOP.
TYPE A NUMBER:? 1
ONE
TYPE A NUMBER:? 5
TYPE A NUMBER:? 25
TYPE A NUMBER:? 1
ONE
TYPE A NUMBER:? 0
```

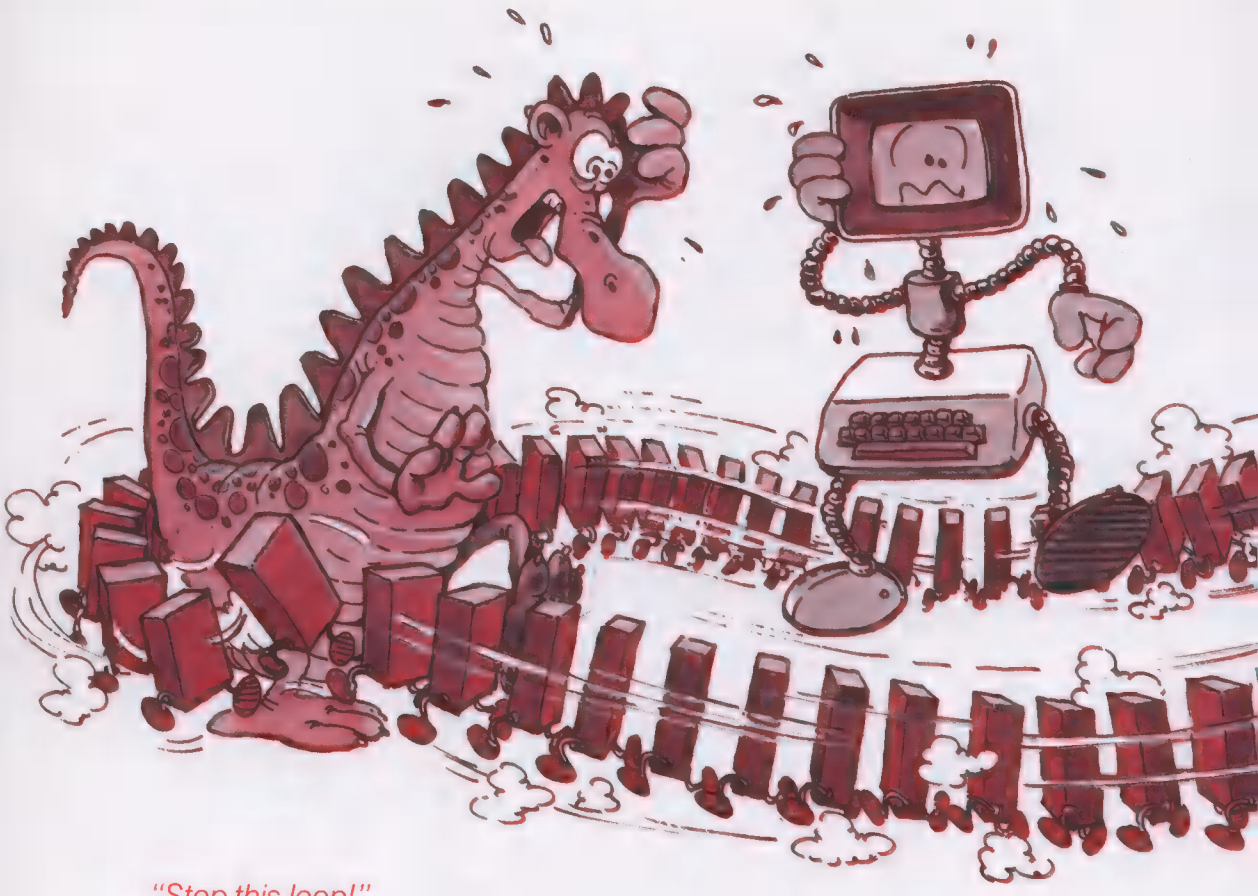
Every time you type 1 the program recognizes it and spells out ONE. Every time you type anything else, the number is ignored and the program requests a new value. The program continually goes back to the beginning. This is called a *loop*. The program is said to loop upon itself. If you type a 0, it is detected by statement 40, and the program jumps to statement 60 and ends.

Let's now remove statement 40. The program looks like this:

```
10  PRINT "THIS PROGRAM RECOGNIZES 1'S. TYPE 0 TO STOP."
20  PRINT "TYPE A NUMBER:"; : INPUT NUMBER
30  IF NUMBER = 1 THEN PRINT "ONE"
50  GOTO 20
60  END
```

Here is a sample run:

```
THIS PROGRAM RECOGNIZES 1'S. TYPE 0 TO
 STOP.
TYPE A NUMBER:? 2
TYPE A NUMBER:? 1
ONE
TYPE A NUMBER:? 0
TYPE A NUMBER:?
```



"Stop this loop!"

Like the apprentice sorcerer, we have created a terrible problem: this program will never stop! This is a common programming error called an *endless loop*. The program may continue executing forever. Don't worry. This will not damage anything. To stop it, you must press either BREAK or SYSTEM RESET. If worse comes to worst, and you can't remember what to do, turn your computer off and then turn it back on again. But remember: if you turn the computer off, you will lose everything you have typed in so far and have not previously saved on cassette or diskette. We will strive to avoid this unpleasant situation by providing a normal (programmed) exit for each program from now on.

Having introduced the GOTO statement, let's now go back to our definition of the IF statement, and simplify it.

IF Statement Revisited

Recall that one of the forms of the IF statement is

IF (logical expression) THEN (line number)

The other is:

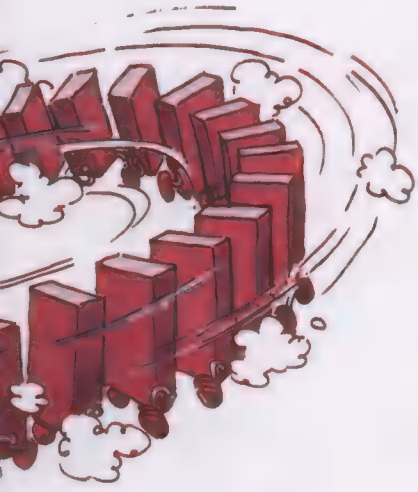
IF (logical expression) THEN (executable statement)

Here is an example of the first form:

```
IF NUMBER = 0 THEN 60
```

This is equivalent to:

```
IF NUMBER = 0 THEN GOTO 60
```



GOTO 60 is an executable statement, and you will recognize that the form

```
THEN 60
```

is simply a convenient shorthand statement for

```
THEN GOTO 60
```

So, in reality, the general form of the IF statement is, in fact, simpler than our previous definition:

IF (logical expression) THEN (executable statement)

Here is one more simplification: the use of THEN before a GOTO is usually optional. With most BASICs, the following forms are all equivalent:

```
IF NUMBER = 0 THEN 100
IF NUMBER = 0 THEN GOTO 100
IF NUMBER = 0 GOTO 100
```

We will now demonstrate the use of IFs and GOTOs on program examples.

Counting Ones

In Chapter 5, we introduced the counter technique. Let's now use it to count the number of 1's typed in the last program of the previous section. Here is the improved program:

```
1   REM ONE'S COUNTER
10  PRINT "I WILL COUNT HOW MANY SINGLE 1'S YOU TYPE"
20  PRINT "TYPE 0 TO STOP"
30  SUM = 0
40  PRINT "TYPE A NUMBER:  "; : INPUT NUMBER
50  IF NUMBER = 0 THEN 100
60  IF NUMBER< >1 THEN GOTO 40
70  SUM = SUM + 1
80  PRINT "ONE. TOTAL SO FAR:  "; SUM
90  GOTO 40
100 END
```

Here is a sample run:

```
I WILL COUNT HOW MANY SINGLE 1'S YOU TYPE.
TYPE A NUMBER: ? 10
TYPE A NUMBER: ? 1
ONE. TOTAL SO FAR: 1
TYPE A NUMBER: ? 9
TYPE A NUMBER: ? 5
TYPE A NUMBER: ? 1
ONE. TOTAL SO FAR: 2
TYPE A NUMBER: ? 2
TYPE A NUMBER: ? 1
ONE. TOTAL SO FAR: 3
TYPE A NUMBER: ? 410
TYPE A NUMBER: ?
```

Let us examine the program. Statements 10 and 20 display messages:

```
10  PRINT "I WILL COUNT HOW MANY SINGLE 1'S YOU TYPE."
20  PRINT "TYPE 0 TO STOP"
```

Statement 30 initializes the counter variable SUM to zero:

```
30  SUM = 0
```

Then the number is collected from the keyboard:

```
40  PRINT "TYPE A NUMBER: "; : INPUT NUMBER
```

If the number is 0, we are done:

```
50  IF NUMBER = 0 THEN 100
```

where 100 is the END statement. Let's assume that the number was 10, and see what happens:

```
60  IF NUMBER< >1 THEN GOTO 40
```

If the number is not 1, then we jump back to 40 and request a new number. If the number is 1, we proceed:

```
70  SUM = SUM + 1
```

The counter variable SUM is incremented by one. Recall the meaning of an assignment statement. You can read line 70 as:

SUM receives the new value of (old value of SUM) + 1

At this point, SUM receives the value 0 + 1 = 1. The next statement is:

```
80  PRINT "ONE. TOTAL SO FAR:  "; SUM
```

Then the program loops back to line 40, requesting a new number:

```
90  GOTO 40
```

Arithmetic Drill Revisited

Recall that we developed an arithmetic drill program at the beginning of this chapter. We regretted the fact that it was too simple and could not recycle. However, we can now make it recycle.

Since the program is rather large, let's look at the relevant segment only. First, here is the section that asks the user to select a number between 1 and 4:

```
90   PRINT "WHAT IS YOUR CHOICE:"; : INPUT CHOICE
100  IF (CHOICE = 1) THEN 200
110  IF (CHOICE = 2) THEN 300
120  IF (CHOICE = 3) THEN 400
130  IF (CHOICE = 4) THEN 500
140  PRINT " INCORRECT CHOICE. YOU MUST SELECT A
     NUMBER BETWEEN 1 AND 4"
150  PRINT "GOOD BYE" : END
```

And here is our improvement:

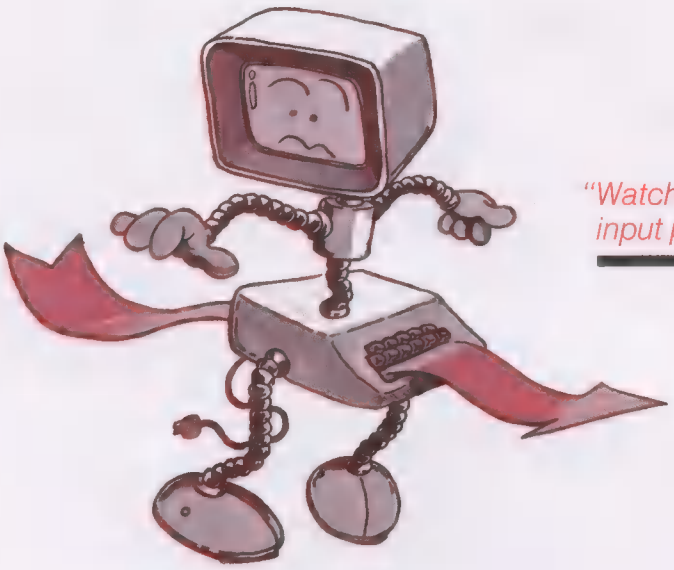
```
150  GOTO 90
```

That is all. Check it.

Now, we would also like the program to present more than one arithmetic question. Say, we want it to ask ten different questions. We could do this by adding GOTO's and a counter.

Validating the Input

The examples we have just examined demonstrate an important rule when designing a program: Whenever you request data at the keyboard, do not assume that it will always be supplied correctly. A user might hit the wrong key, either deliberately or accidentally. To avoid strange or erroneous program behavior, always *validate the*



"Watch my input please."

input. If the information typed at the keyboard is not valid, generate a polite message and request the input again. We will perform input validation in most of our examples.

Let's now develop two complete programs that make decisions.

Mileage Conversion

In Chapter 3, we learned how to perform a simple conversion of miles into kilometers. Here is a way to automate it:

```
10   REM * * * MILEAGE CONVERSION * * *
20   REM
30   PRINT "I CONVERT MILES INTO KILOMETERS"
40   PRINT "TYPE 0 TO STOP"
50   PRINT "HOW MANY MILES  "; : INPUT MILES
60   IF MILES = 0 GOTO 100
70   KM = MILES * 1.6
80   PRINT MILES; " MILES =  "; KM; " KILOMETERS"
90   GOTO 50
100  END
```

Here is a sample run:

```
I CONVERT MILES INTO KILOMETERS
TYPE 0 TO STOP
HOW MANY MILES? 7
7 MILES = 11.2 KILOMETERS
HOW MANY MILES? 10
10 MILES = 16 KILOMETERS
HOW MANY MILES? 0
```

Birthday

Here is one more example. Let's now improve our earlier program that computed a person's age. You will supply today's date and the year, month, and day you were born, and the program will tell you your exact age. Here is the program:

```
10  REM * * * AGE COMPUTATION * * *
20  DIM FIRST$(10)
30  PRINT "WHAT IS YOUR FIRST NAME?"; : INPUT FIRST$
40  PRINT "HELLO "; FIRST$; " ! WILL COMPUTE YOUR
    AGE"
50  PRINT "WHAT IS TODAY'S DATE? (YY/MM/DD)"
60  PRINT "THE YEAR FIRST (2 DIGITS): "; : INPUT YY
70  IF (YY<0 OR YY>99) THEN 50
80  PRINT "THE MONTH (1 TO 12) : "; : INPUT MM
90  IF (MM<1 OR MM>12) THEN 70
100 PRINT "THE DAY: "; : INPUT DD
110 IF (DD<1 OR DD>31) THEN 90
120                                              REM
130 PRINT "NOW GIVE ME YOUR BIRTHDATE"
140 PRINT "YEAR (2 DIGITS) : "; : INPUT YBORN
150 IF (YBORN<0 OR YBORN>99) THEN 140
160 PRINT "MONTH (1 TO 12) : "; : INPUT MBORN
170 IF (MBORN <1 OR MBORN>12) THEN 160
180 PRINT "DAY: "; : INPUT DBORN
190 IF (DBORN<1 OR DBORN>31) THEN 180
200                                              REM
210 REM - - - - - AGE COMPUTATION - - - - -
220 IF MBORN<MM THEN 270
230 IF MBORN>MM THEN 320
240 REM - - - - - BIRTHDAY THIS MONTH - - - - -
250 IF DBORN<DD THEN 270
260 IF DBORN>DD THEN 320
270 PRINT "TODAY IS YOUR BIRTHDAY. CONGRATULATIONS"
280 AGE = YY - YBORN
290 PRINT "YOU ARE "; AGE; "YEARS OLD"
300 END
310                                              REM
320 REM BIRTHDAY NOT YET REACHED THIS YEAR
330 AGE = YY - YBORN - 1
340 GOTO 280
350 END
```

Despite its length, this program is quite simple. Note how we

validate each input. However, to keep the program short our validation is rough. We do not verify that each number is an integer. Nor do we verify the number of days in each month. This is left as an exercise for the thorough (and patient) reader.

Here is a way you could check that MM is equal to an integer between 1 and 12:

```
IF NOT (MM = 1 OR MM = 2 OR . . . MM = 12) THEN 70
```

Summary

Using the IF and the GOTO statements, we have learned how to write programs to perform tests on values and to make decisions. We have also learned how to perform program loops so that a portion of a program can be repeated indefinitely. In addition, we have learned how to systematically check and validate inputs typed at the keyboard. We have now learned all the basic skills required to write common programs, and we have examined several meaningful examples as well. We will now make our programs more convenient to write.

Because of the frequency and importance of loops and automation in programs, Atari BASIC offers additional facilities in the form of additional statements. We will discuss these facilities in the next chapter.

Exercises

6-1: What is the use of the IF statement?

6-2: What is the effect of the following:

```
5   DIM  ANSWER$ (3)
10  INPUT ANSWER$
20  IF (ANSWER$ = "YES") THEN PRINT "THANK YOU"
30  IF (ANSWER$ = "NO") THEN PRINT "TOO BAD"
40  PRINT "YES OR NO" : GOTO 10
```

If the result of the above is illogical, suggest a better program.

6-3: Are the following logical expressions valid?

a. A = 4

b. B = 2 OR C = 3

c. A > 5

d. 5 > A

e. 1 > 2

f. SUM > NUMBER

g. LETTER$ = "A"

6-4: Is the following valid?

```
10  IF A = 5 THEN IF B = 2 THEN 18
```

6-5: What is a program loop?

Automating

7

Using the IF and the GOTO statements, we can execute a program segment repeatedly. The corresponding program segment is called a loop; and most programs use loops. In this chapter we will learn improved techniques for creating loops. We will also develop sophisticated programs that automate tasks.

We will begin this chapter with a review of the IF/GOTO technique of generating a loop. We will then introduce a new statement, the FOR . . . NEXT statement, designed to facilitate the creation of loops. We will use this important statement extensively in our programs.

Repetitions

The IF/GOTO Technique

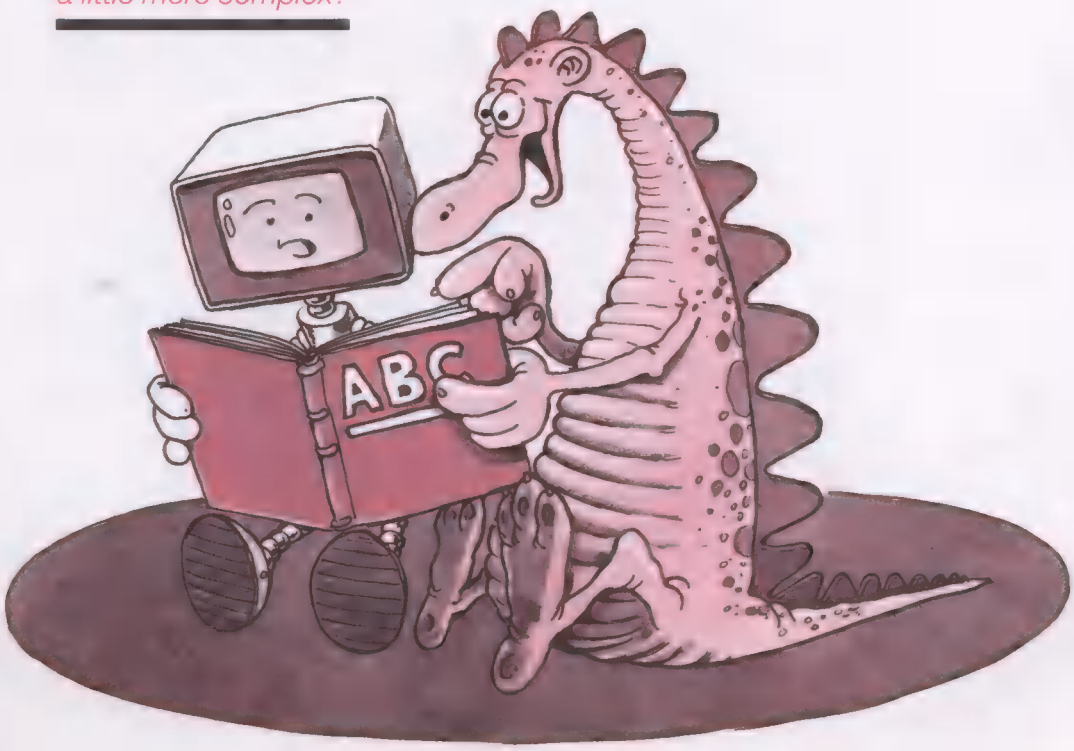
We will begin by examining a program that automates a loop, using the IF/GOTO technique. As we examine this program we will point out certain features common to all loops. For example, we will examine the use of a counter variable, incrementation, initialization, and test before exit. Here is the program. It computes the sum of the first ten integers.

```
1   REM * * * SUM OF FIRST 10 INTEGERS * * *
10  SUM = 0
20  I = 1
30  SUM = SUM + I
40  I = I + 1
50  IF I = 11 THEN 70
60  GOTO 30
70  PRINT "THE SUM OF THE FIRST 10 INTEGERS IS:  "; SUM
80  END
```

Two variables are used in this program: SUM and I. The variable SUM accumulates the sum of the first 10 integers as we keep adding them—it is the equivalent of a subtotal on a calculator. I is the integer that is being added to SUM.

Recall that a variable must have a value the first time it is used. Thus, before we use SUM and I in a formula, we must set their values to an *initial* value (0 and 1, respectively). This is accom-

"How about something a little more complex?"



plished by statements 10 and 20. These statements are called *initialization* statements.

The next statement is:

```
30  SUM = SUM + I
```

This statement adds the value of the current integer I to the current SUM. When this statement is executed for the first time, the value of SUM is 0 and the value of I is 1. As a result this statement assigns the value 0 + 1 = 1 to SUM. Following execution of that statement, SUM contains the value 1.

The next statement is:

```
40  I = I + 1
```

The current value of I is 1. The result of this statement is to give I the new value, 2. This is the counter technique: I is incremented by one in order to generate the next integer. At the same time, the value of I indicates how many integers have been added so far. In other words, I is used as the current integer and as a counter.

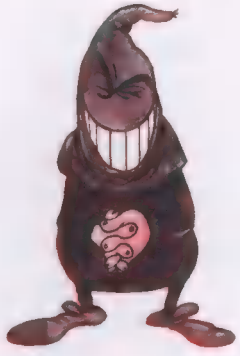
"Remember me?"

So, all we have left to do is to go back to statement 30 and keep adding integers:

```
50  GOTO 30
```

Wrong. This program will (in theory) never stop (actually it will once the value of SUM becomes larger than the maximum allowed by your interpreter). This is not what we want. We want the program to stop after executing the loop ten times. We must introduce a *test* instruction. Here it is:

```
50  IF I = 11 THEN 70
```



"Got you again!"

Once I reaches the value 11, statement 70 is executed and the program stops. This is called *exiting* from the loop. Let's now verify that the value 11 (rather than 10) is indeed correct in statement 50. If we write:

```
50  IF I = 10 THEN 70
```

It does not work. Once I reaches the value 10, SUM contains the sum of 1 through 9 only. The loop should be executed one more time.

Remember that each loop contains a counter. You should always carefully check the value of the counter that causes exit from the loop. In our example, as long as I is not equal to 11, the loop will be reentered:

```
60  GOTO 30
```

Once I reaches the value 11, the first ten numbers will have been added. This is because in our program the addition (SUM = SUM

+ I) takes place before the incrementation (I = I + 1). The final two statements in the program are the *exit* from the loop:

```
70  PRINT "THE SUM OF THE FIRST TEN INTEGERS IS:  ";  SUM
80  END
```

Here is a sample run of this program:

```
THE SUM OF THE FIRST 10 INTEGERS IS: 55
```

The illustration in Figure 7.1 shows the flow of control in the program. The numbers in parentheses are the statement numbers.

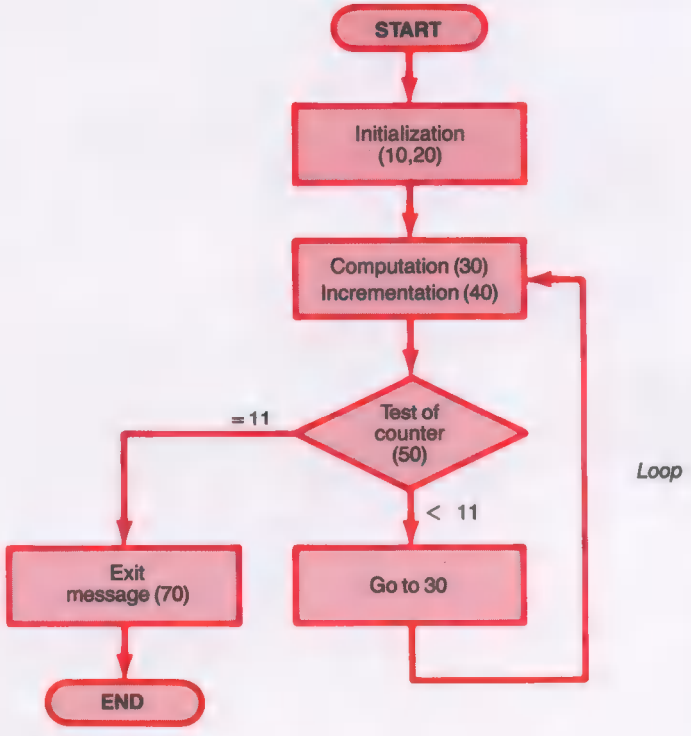


Figure 7.1 Flow control in the Integer SUM Program

This diagram is called a *flowchart*. We will discuss the subject of flowcharts in detail in Chapter 8. For now, simply note the general organization of the program: initialization, computation plus incrementation, test, and exit. All program segments with loops perform these functions.

Variations

Let's now play with our integer addition program and sharpen our programming skills. This will demonstrate the many alternatives

that can be used to write a program. For example, on line 50 we could have written:

```
50  IF I > 10 THEN 70
```

and the result would be the same (when I reaches the value 11, it is greater than 10). Also, we could have written:

```
40  IF I = 10 THEN 70
50  I = I + 1
```

instead of:

```
40  I = I + 1
50  IF I = 11 THEN 70
```

With this change, I is tested first, then incremented. Note that this time I is tested for the value 10 (instead of 11).

We could also have written:

```
50  IF I < 11 THEN 30
60  REM
```

You can verify that these versions are indeed correct. All these variations are valid and equivalent. Even such a short program as the SUM program can be written in many equivalent ways. There is no unique way to write a program. Just like in a spoken language, you can express the same concept in many different ways.

This short program has illustrated the use of a loop and the use of a counter variable. We have also examined the typical phases involved in such a program: initialization, computation, incrementation, test, and exit. In view of the frequent use of loops in programs, a special statement has been provided to facilitate their use in BASIC. This is the FOR . . . NEXT statement.

The FOR . . . NEXT Statement

The FOR . . . NEXT statements automate much of the programming required for a loop. We will explain their use and operation by using actual examples.

Here is one way we can rewrite our addition program using these new statements:

```
1   REM * * * INTEGER ADDITION – VERSION 2 * * *
10  SUM = 0
20  FOR I = 1 TO 10
30  SUM = SUM + I
40  NEXT I
50  PRINT "THE SUM OF THE FIRST 10 INTEGERS IS:  "; SUM
60  END
```

Note that this program has two less instructions than the first one. It is shorter and more readable. Let's examine it in detail. The first executable statement initializes SUM to zero:

```
10  SUM = 0
```

The next statement is the FOR instruction:

```
20  FOR I = 1 TO 10
```

This instruction has several roles:

- It marks the beginning of the automatic loop. (This is where the loop starts.)
- It specifies that I (the counter variable) starts with the initial value 1 when this statement is first executed. This eliminates the need for an initialization statement for I.
- I is incrementated by 1 (up to a maximum value of 10) every time the statement is reactivated by a matching NEXT statement. An automatic test is performed, and when I exceeds the value 10, the loop is no longer executed, and the statement following the NEXT is executed instead. (This is the loop exit).

The body of the loop simply contains the accumulation of the sum:

```
30  SUM = SUM + I
```

The NEXT statement:

```
40  NEXT I
```

marks the end of the loop and causes reactivation of the FOR. This replaces two statements in the previous version:

```
40  I = I + 1
60  GOTO 30
```

Every time NEXT I is executed, the program jumps to the beginning of the loop , i.e., the FOR statement. When FOR is activated:

- I is incremented by 1
- the new value of I is automatically compared to 10.

As long as I does not exceed 10, execution proceeds. The looping stops when I equals 10, and NEXT is reached. At this point, exit occurs, and statement 50 (following the NEXT) is executed. This sequence is illustrated in Figure 7.2 (a flowchart).

Figure 7.2 shows that the FOR statement automates three tasks:

- initialization of the counter variable (I is set to 1 initially)
- incrementation of the counter variable (I is incremented by 1 each time)
- test of the counter variable against a maximum value (I is compared to 10).

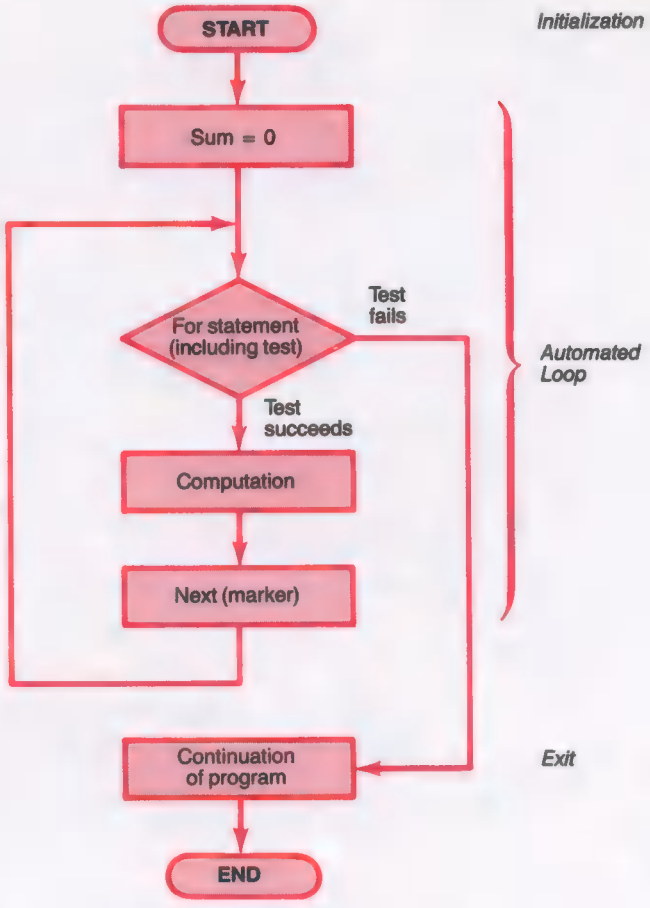


Figure 7.2: Automatic looping with FOR . . . NEXT

The NEXT statement simply marks the end of the loop and causes a "GOTO the FOR" statement. After using the FOR statement a few times, you will appreciate how it simplifies loop design and clarifies the program.

FOR . . . NEXT is a convenience statement. You do not have to use it, but you will probably find it very valuable. Generally, the clearer the program, the less the risk of errors. We will now give practical examples to illustrate the use of the FOR . . . NEXT statement and the use of automated loops.

Sum of the First N Integers

We will compute the sum of the first N integers. This time the user specifies the value of N at the keyboard. Here is the program:

```
10  REM * SUM OF FIRST N INTEGERS *
20  SUM = 0
30  PRINT "I WILL ADD THE FIRST N INTEGERS. TYPE N: ";
    : INPUT N
40  FOR I = 1 TO N
50  SUM = SUM + I
60  NEXT I
70  PRINT "THE SUM OF THE FIRST  "; N; "INTEGERS IS  "; SUM
80  END
```

Here is a sample run:

```
I WILL ADD THE FIRST N INTEGERS. TYPE N: ? 5
THE SUM OF THE FIRST 5 INTEGERS IS 15
```

You should understand the program readily. This time, we loop from 1 to N, where N is supplied at the keyboard (statement 30). You can improve this program by validating the input: N should be greater than 1. The BASIC interpreter will automatically verify that N is an integer when executing the FOR statement. Try fooling it.

Tables of Values

Using the powerful FOR . . . NEXT statement, we will show how easy it is to automate computations and print tables of values. Here is a table of squares (a number multiplied by itself) and cubes (a number multiplied by itself and multiplied by itself again):

```
10  REM TABLE OF SQUARES AND CUBES
20  REM FOR THE FIRST 10 INTEGERS
30  FOR I = 1 TO 10
40  PRINT I, I ^ 2, I ^ 3
50  NEXT I
60  END
```

Here is the result:

```
1         1         1
2         4         8
3         9         27
4         16        64
5         25        125
6         36        216
7         49        343
8         64        512
9         81        729
10        100       1000
```

Let's take a closer look at statement 40:

```
40  PRINT I, I ^ 2, I ^ 3
```

I ^ 2 means I to the power 2. For example, if I = 2, then I ^ 2 = 2 × 2 = 4. Similarly, I ^ 3 means I to the power 3. If I = 4, then I ^ 3 = 4 × 4 × 4 = 64.

Notice that we use a comma this time in the PRINT statement so that the results are neatly aligned as they are listed. The comma forces an automatic spacing (or *tabulation*) on the line. The exact spacing between columns in Atari BASIC is seven characters.

As an exercise you could rewrite this program to display the sum of the squares and cubes of the first N integers, where N is read at the keyboard. We learned how to do this in the previous section.

Lines of Stars

Here is a simple program that prints N lines of stars, where N is a number you specify at the keyboard:

```
10  REM * LINES OF STARS *
20  PRINT "I WILL DISPLAY LINES OF STARS"
30  PRINT "TELL ME HOW MANY LINES :"; : INPUT N
40  REM N IS THE NUMBER OF LINES TO BE DISPLAYED
50  FOR I = 1 TO N
60  PRINT "****************************************"
70  NEXT I
80  END
```

And here is a sample run of this program:

```
I WILL DISPLAY LINES OF STARS
TELL ME HOW MANY LINES : ?6
****************************************
****************************************
****************************************
****************************************
****************************************
****************************************
```

Again, every time an input is supplied by the user, it is a good idea to validate it in order to avoid strange program behavior. We expect that the person using this program will supply a positive number. Let's assume you want no more than 20 lines of stars. You would tell the user in an appropriate PRINT statement, and use a validation statement like:

```
IF (N<1) OR (N>20) THEN GOTO 20
```

Advanced Looping

The FOR . . . NEXT statement offers two advanced facilities that we have not yet described:

- You can increment the counter by any integer value, such as 2, 3, 4, or even –1 (rather than just incrementing by 1). This is called the *variable step* feature.
- You can create a loop within another loop. Such loops are called *nested loops*.

Let us examine these two techniques.

Be careful when looping

Variable Step

Here is an example of variable step:

```
FOR I = 1 TO 5 STEP 2
```

Every time the loop is re-entered I will be incremented by 2. You could even write:

```
FOR I = 10 TO -5 STEP -1
```

using a *negative step* increment. Because the upper limit for the counter variable (−5 here) is less than the starting value (10), it is a "negative step" for the interpreter. The value of I will be decreased by 1 each time. The first value of I will be 10. The next will be 9; the next 8, etc. The last one will be −5. In other words, I will take the following values in turn: 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0, −1, −2, −3, −4, −5. Negative step is another convenience feature that you may want to use.

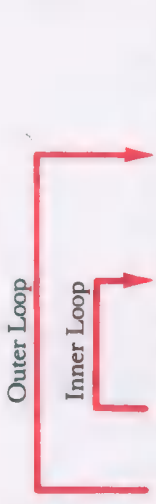
Your variable may use step increases

Nested Loops

The nested loop technique is an important and powerful facility used to automate complex processing. A nested loop is created whenever you use a FOR . . . NEXT group of statements within a loop; that is, whenever you use another FOR . . . NEXT group of statements.

In general, you may use as many statements as you wish between the FOR and the NEXT statements. Specifically, you may even include another loop within these statements. When this takes place it is called a nested loop. This concept is illustrated in Figure 7.3.

When using nested loops, notice how the program becomes more difficult to read. To remedy this, you are encouraged to use *indentation*. Indentation is another program clarification technique. Figure 7.4 shows an indented version of the program of Figure 7.3.



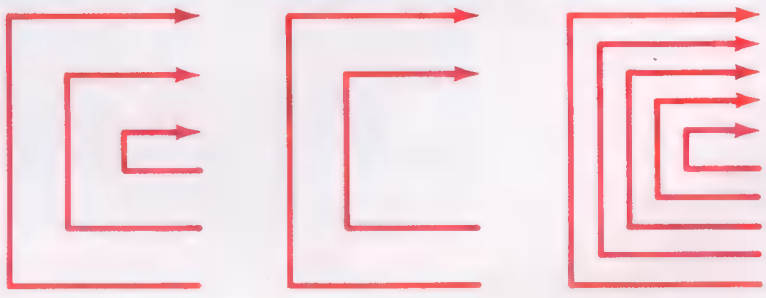

```
STATEMENT
STATEMENT
STATEMENT
FOR
STATEMENT
STATEMENT
FOR
STATEMENT
STATEMENT
NEXT
STATEMENT
NEXT
STATEMENT
STATEMENT
STATEMENT
END
```

Figure 7.3: A nested loop

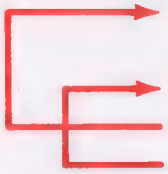
```
STATEMENT
STATEMENT
STATEMENT
FOR
    STATEMENT
    STATEMENT
    FOR
        STATEMENT
        STATEMENT
    NEXT
    STATEMENT
NEXT
STATEMENT
STATEMENT
STATEMENT
END
```

Figure 7.4: An indented program

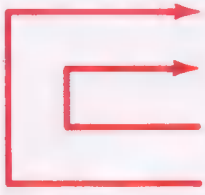
You can nest loops to any level, up to a maximum number which depends on the amount of memory you have. (If that limit is exceeded, the computer will display the message ERROR-2, which means you have run out of memory. However, you may not overlap loops. The following loops are legal:



The following are not legal:



In addition, you may not jump (i.e, specify a GOTO) from a point *inside* the outer loop to a point inside the inner one:

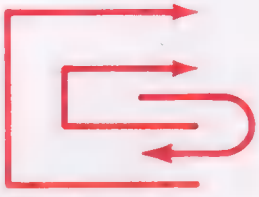


Correct nesting

Illegal jumping
(with IF or GOTO)

However, you may jump out of the inner loop:

Correct jumping



Correct jumping

Here is an example of a nested loop. This program displays accelerated time in minutes and hours:

```
10  REM * * * SIMULATED CLOCK * * *
20  FOR HOUR = 0 TO 23
30      FOR MINUTE = 0 TO 59
40          PRINT "THE TIME IS "; HOUR; " HOURS AND ";
            MINUTE; " MINUTES"
50      NEXT MINUTE
60  NEXT HOUR
70  PRINT "END OF THE DAY"
80  END
```

Here is a portion of the run:

```
THE TIME IS 0 HOURS AND 0 MINUTES
THE TIME IS 0 HOURS AND 1 MINUTES
THE TIME IS 0 HOURS AND 2 MINUTES
THE TIME IS 0 HOURS AND 3 MINUTES
THE TIME IS 0 HOURS AND 4 MINUTES
                    .
                    .
                    .
THE TIME IS 0 HOURS AND 59 MINUTES
THE TIME IS 1 HOURS AND 0 MINUTES
```

Additional Features

As a final note, decimal values and expressions are allowed in the FOR statement. For example, the following are valid:

```
FOR MEASURE = 0.1 TO 13.5 STEP 0.2
FOR NUMBER = N TO (N * 2) STEP 1
```

This practice is not recommended; and we will not use these advanced features here.

Summary

Loops are used extensively to automate the repetition of a program segment. The FOR . . . NEXT statement is used to automate loops in BASIC. In most cases, the FOR . . . NEXT statement can replace several other BASIC statements. In this chapter, we have examined typical uses of the FOR . . . NEXT statement, including nested loops, and we have developed several advanced programs. Now that you have learned all the basic programming techniques, you are almost ready to start writing your own programs. In the next chapter we will explain how you can get started.

Exercises

7-1: Display the first 12 integers on a line (4 statements).

7-2: Write a program that reads the time in hours and minutes at the keyboard and displays it as follows:

Input:	3 *(hours),*	*3 (minutes)*
Display:	H H H	*(3 letters)*
	M M M	*(3 letters)*

7-3: What is the counter variable in a loop?

7-4: Can you jump into the middle of a loop?

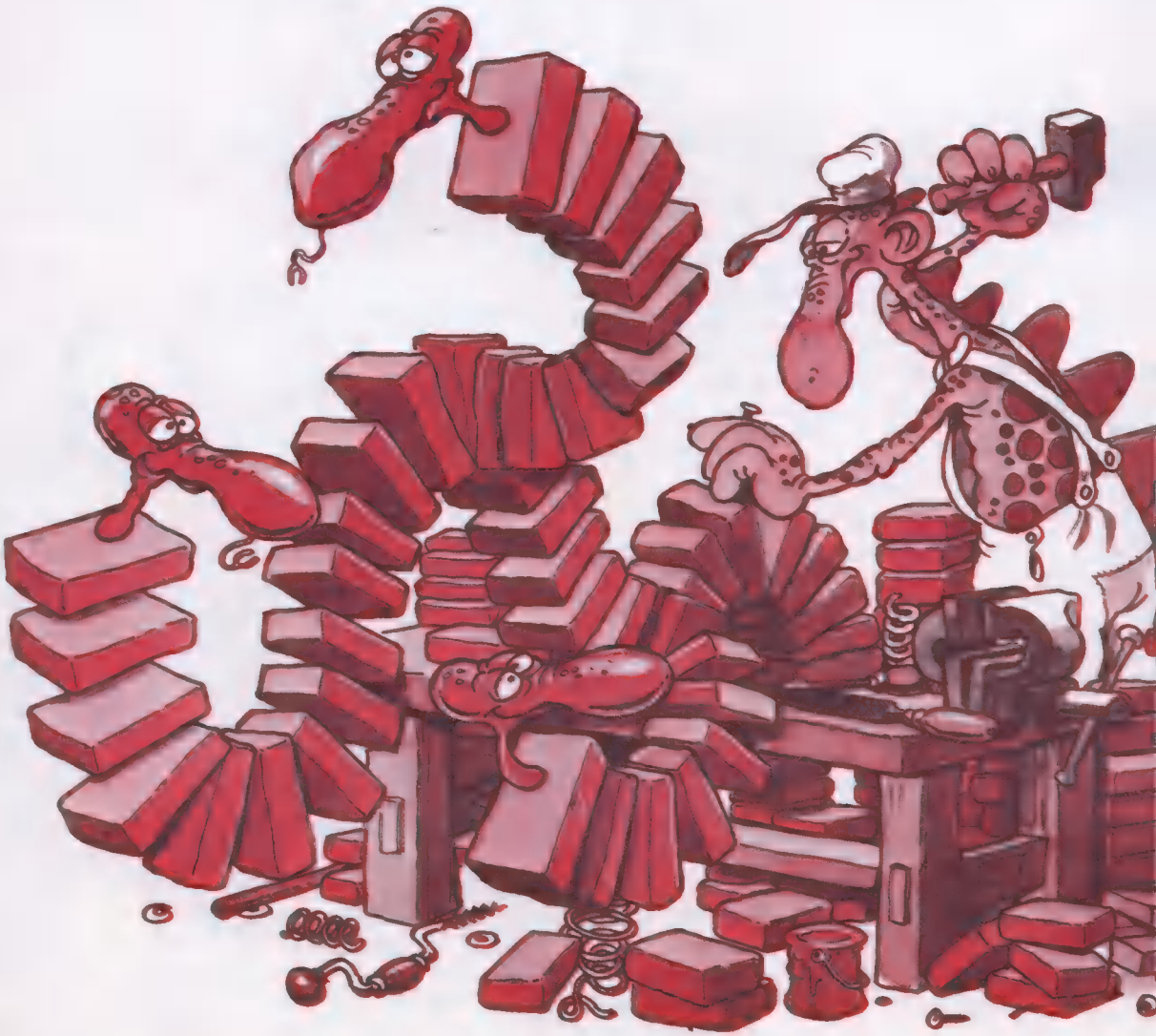
7-5: Display a table that converts ounces to grams (1 ounce = 28 grams).

7-6: Compute the sum of the first N odd integers—where N is supplied at the keyboard—and display it for each integer.

7-7: Read scores for five students that each took four tests, graded 0 to 10. Display the grades, then the total and average for each.

7-8: Display a sales tax table for prices of $1 to $100 in $1 increments. Supply the tax rate at the keyboard.

Creating a

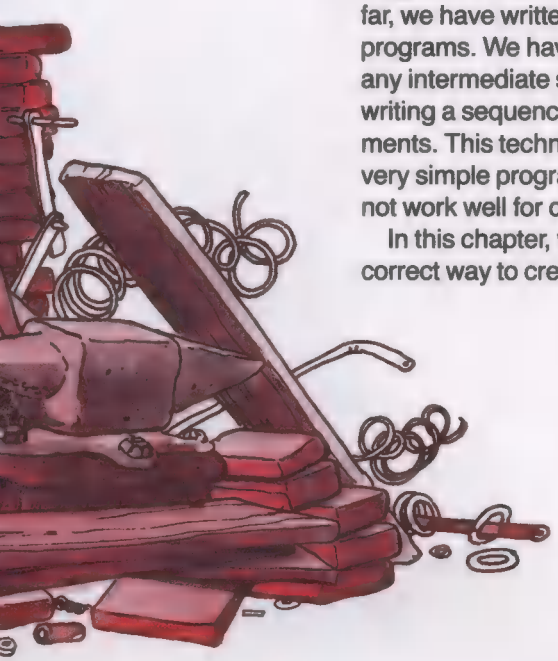


Program

8

Programming involves designing a program that automates a task. So far, we have written several short programs. We have done so without any intermediate steps—directly writing a sequence of BASIC statements. This technique is fine for very simple programs, but it does not work well for complex ones.

In this chapter, we will learn the correct way to create a program.



This is a five-step process:

1. Specify the sequence of steps involved in solving the problem. This is called designing the *algorithm.*
2. Draw a diagram showing the sequence of events and the logical steps. This is called drawing the *flowchart.*
3. Write the program in BASIC. This is called *coding.*
4. Verify and test the program. This is called *debugging.*
5. Clarify and document the program. This is called *documenting.*

So far, we have only learned and practiced steps 2 and 5. But this sequence will work only for short programs. Before we proceed to long programs, let's study the complete sequence involved in program development.

Algorithm Design

We want to design a program that will solve a given problem or automate a task. So far, we have designed programs to solve simple problems. The sequence of steps required to solve each problem was generally obvious, so there was almost no design phase. In the general case, however, given a problem we must first design a solution. In order to write programs, this solution must be specified as a sequence of steps. This sequence of steps is called an *algorithm*. Formally, an algorithm is defined as a step-by-step specification of the solution to a problem. Technically, an algorithm must also terminate—it should not go on indefinitely. An algorithm that does not stop is called an *error!*

Here is a simple problem: let's convert a weight measured in ounces into its equivalent in grams. Recall that one ounce is equivalent to 28.35 grams. The solution is obvious: we multiply the weight in ounces by 28.35. This is a simple one-step algorithm.

Let's now examine a slightly more complex problem: let's read a number at the keyboard and test that it is within a certain range. We will accept the number as being valid if it falls in the range between 0 and 100. The sequence of steps involved in solving this problem is the following:

1. Read the number.
2. Check to see if it is greater than zero. If so, proceed; if not, reject the number.
3. Check to see if it is less than 100. If yes, accept the number; if not, reject it.

This is a 3-step algorithm.

In practice, most problems are more complicated, and their solutions require longer and more complex algorithms. Here are several everyday examples of algorithms. You can find many more in your cookbook, or in your car or appliance manuals.

Let's examine an algorithm for boiling a three-minute egg. Here are the steps:

1. Take a pan
2. Fill it with water
3. Turn on the stove
4. Place the pan of water on the stove
5. Bring the water to a boil
6. Place an egg in the boiling water
7. Start the three-minute timer
8. When the timer rings, remove the egg
9. Turn off the stove.

"I'll demonstrate the three-minute egg algorithm."

This algorithm looks straightforward, but if it were to be executed as a program by a computerized robot, it would have to be much more precise. For example, we would need to specify exactly which pan to use, as well as the precise amount of water to put in the pan.

Many algorithms presented in everyday books assume that the user has a specific cultural or technical background; and they are therefore generally incomplete. In other words, they assume that a user can fill in the blanks. Unfortunately, this is precisely why so many manuals are so difficult to comprehend!

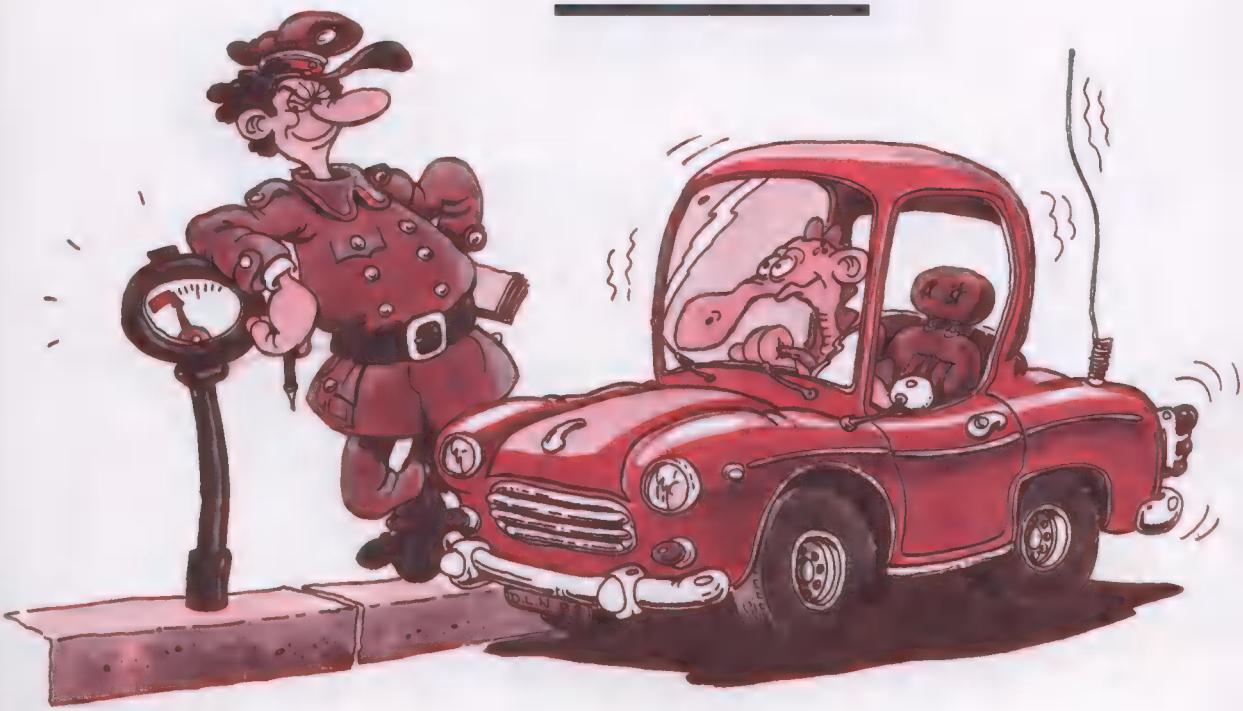
We will not make the same mistake here. Our algorithms will be completely specified in order to become useable programs.

Here is one last example: an algorithm for starting a car. If we assume that the car works perfectly, the algorithm is quite simple:

1. Insert the key in the ignition.
2. Turn the key all the way to the right.
3. Release pressure on the key while applying gentle pressure on the gas pedal.

However, we know that it is possible that a car may not start. This is because there are other factors involved, such as temperature, or the mechanical condition of the engine. Preparing a complete algorithm for starting a car under all conditions would require several pages—if we are to take into account everything that could possibly go wrong.

Starting a car is an interesting algorithm



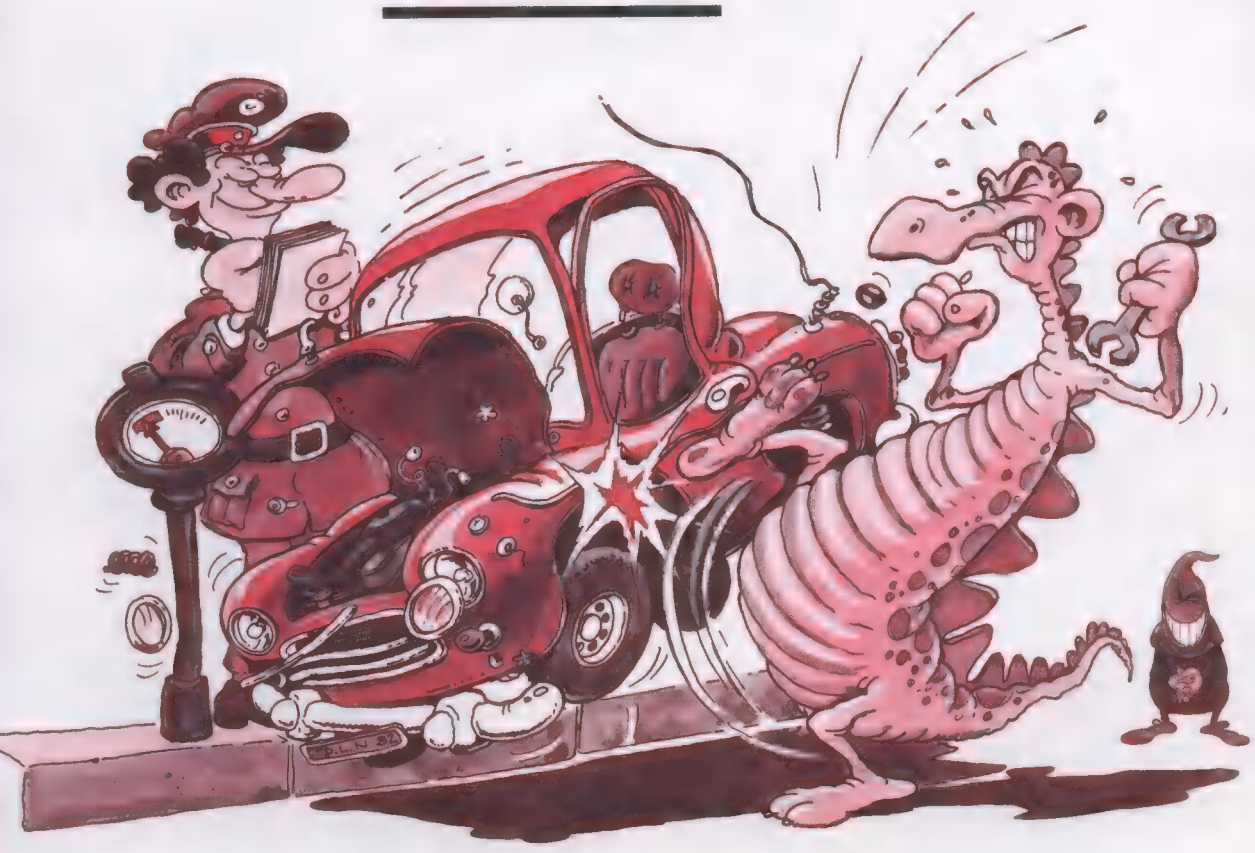
In everyday life we can often simplify the steps of an algorithm. But, in a computer program we may not. An algorithm has to be correct and complete.

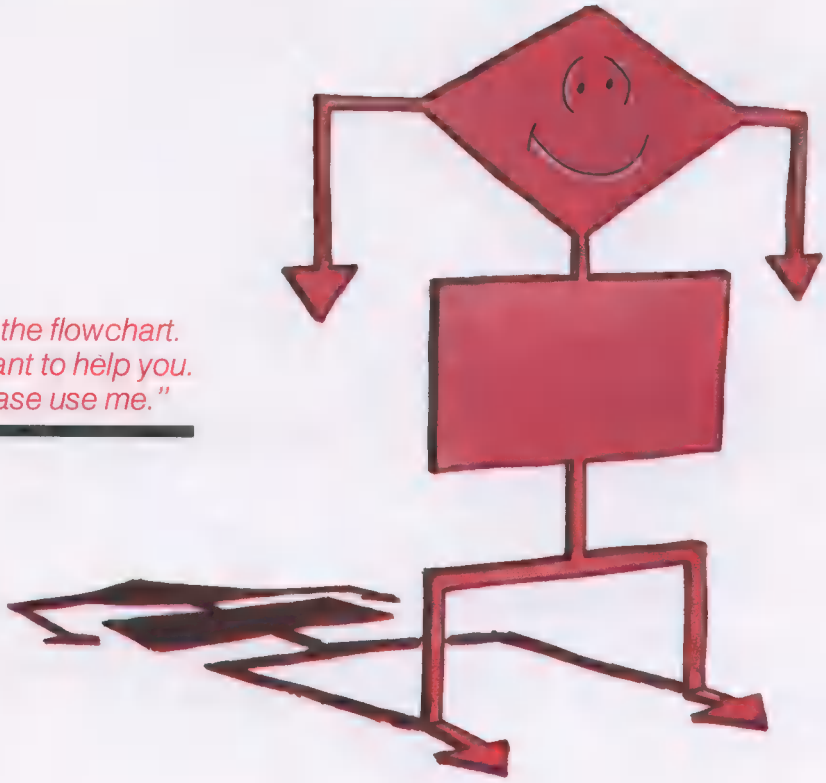
When designing an algorithm for a computer solution, you must be thorough and anticipate every reasonable case that may arise, or your program may eventually fail. Successful programming requires a special attitude: you must continuously challenge everything you do, always assuming that it could be wrong or incomplete.

Never assume an input will be reasonable. Check it and verify it. Always allow for the possibility of errors. We will illustrate these considerations later in this chapter when we examine an actual case study.

In summary, in order to automate the solution to a problem by writing a computer program, start by preparing an algorithm. The final algorithm should be perfect—although, in the beginning it rarely is. In fact, you will probably design an approximate solution (i.e., a rough algorithm) in the beginning and then continue to refine the algorithm as you go along, until it reaches the state you consider to be perfection. Always make sure your algorithm is complete before you start actually writing instructions.

Remember, the algorithm is supposed to work!





"I'm the flowchart. I want to help you. Please use me."

Flowcharting

So, we have designed an algorithm. The thought that now comes to mind is: let's translate it promptly into a BASIC program and run it! Wrong. There is one more step that may save you hours of programming time: it is called flowcharting. If you skip this step, you will probably not write a working program, and you will probably waste much time later trying to correct the program—with no guarantee of success. By contrast, once you have a good flowchart, writing the program is one easy step away.

A flowchart is simply a diagram showing the sequence of events. Figure 8.1 shows a flowchart of the steps involved in boiling a 3-minute egg.

As you can see, this flowchart is a graphic representation of the algorithm we have already presented. In this case, each box in the flowchart represents one step of the algorithm. The purpose of a flowchart is to show the sequence of the steps over time. Later, once you become familiar with flowcharting, you may even skip the algorithm design step and begin directly with flowcharting, since the flowchart is just a representation of the algorithm.

In the case of an algorithm as simple as the one for preparing a 3-minute egg, the flowchart is not very useful and could be dispensed with. The true value of a flowchart becomes apparent when you begin designing more complex algorithms that involve numerous choices and decisions.

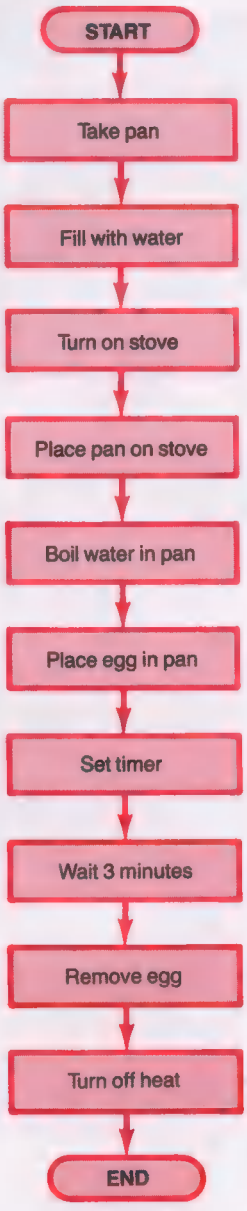


Figure 8.1
Boiling a 3-minute egg

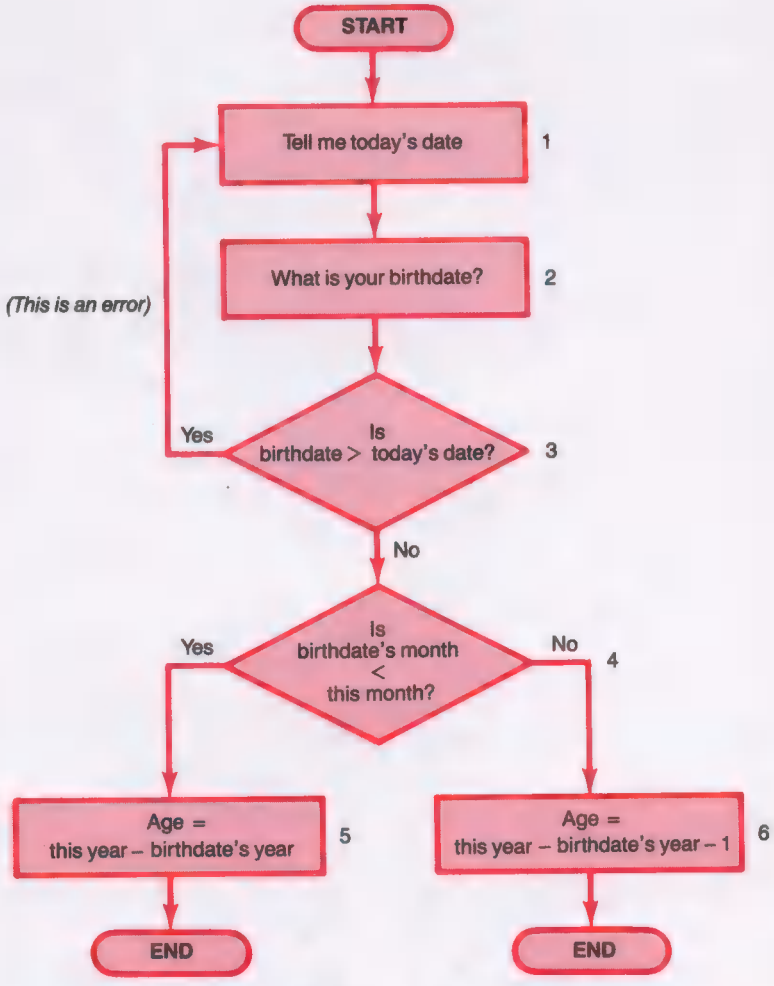


Figure 8.2 Age Computation flowchart

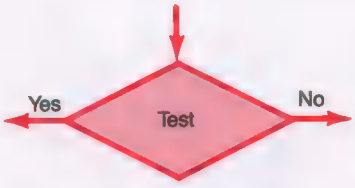


Figure 8.3 Diamond symbol

Let's now design a new program that asks for your birthdate and the current date, and then computes your age. The algorithm is obvious. The flowchart is shown in Figure 8.2. The diamond-shaped boxes in the flowchart indicate a test, i.e., a choice in the sequence. At this point, to facilitate converting the flowchart into a program, make sure that each choice has only *two* results: "yes" or "no." Label the arrows accordingly. Now examine Figure 8.2 and verify that each arrow coming out of the diamond-shaped boxes is labeled either "yes" or "no," depending on the result of the test (see Figure 8.3).

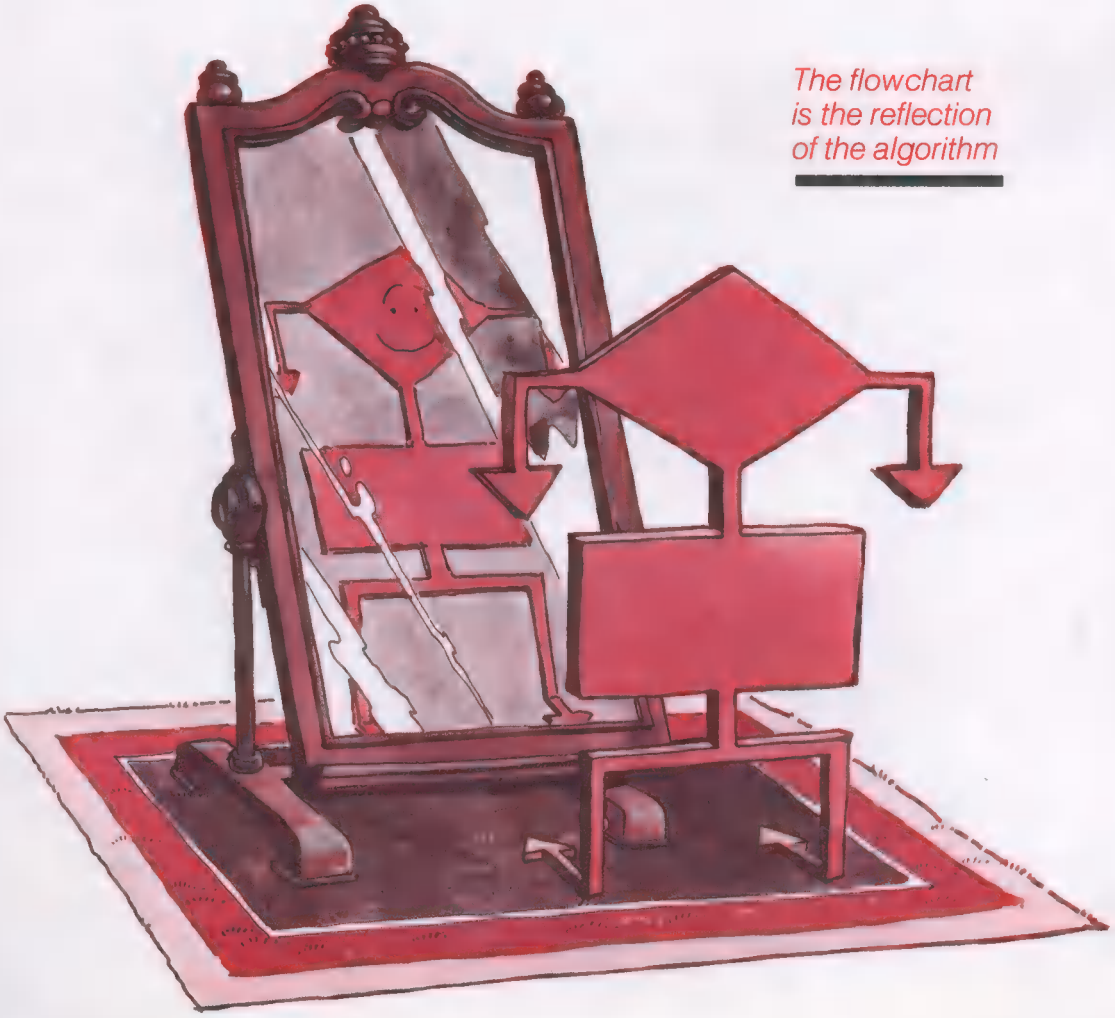
In general, there are three ways the arrows can be drawn, as shown in Figure 8.4. You may select any way you prefer. The purpose of your selection should simply be to facilitate reading the flowchart. The position of the yes and the no arrows may be freely exchanged; in other words, "yes" can be on the right if you prefer.

Let's now go back to Figure 8.2 and the age computation flowchart and examine the algorithm it represents.

First, today's date is requested. This step corresponds to the first box in the flowchart (labeled 1). Second your birthdate is requested. This is the box labeled as 2 on the flowchart.

Next, we must verify that the birthdate supplied is reasonable. We must check that the birthdate is earlier than today's date. If the value of the date of your birthdate is greater than the value of today's date, an error will be recognized and the process will be restarted. If not, the birthdate will be presumed valid. This step corresponds to the diamond shaped box (labeled 3) on the flowchart.

To be even more refined, we could also reject birthdates that result in an age of 150 years or more, since they are unlikely to be valid. However, accepting such birthdates does not create serious adverse effects; therefore it may not be worth the trouble to check for them.



The flowchart is the reflection of the algorithm

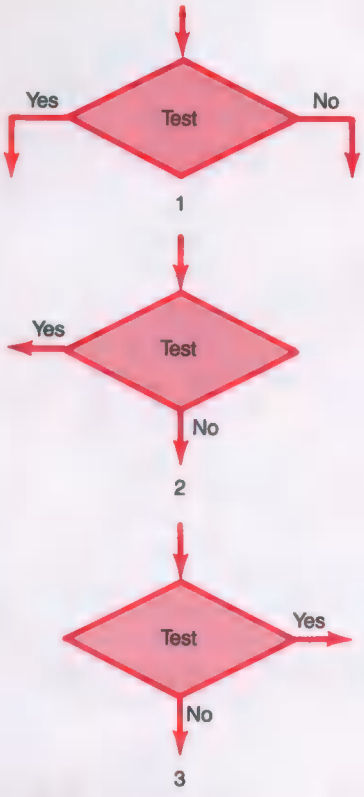


Figure 8.4 The three ways to draw arrows

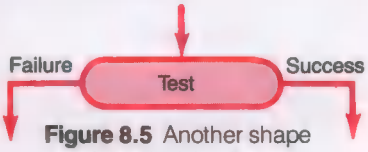


Figure 8.5 Another shape for a decision box

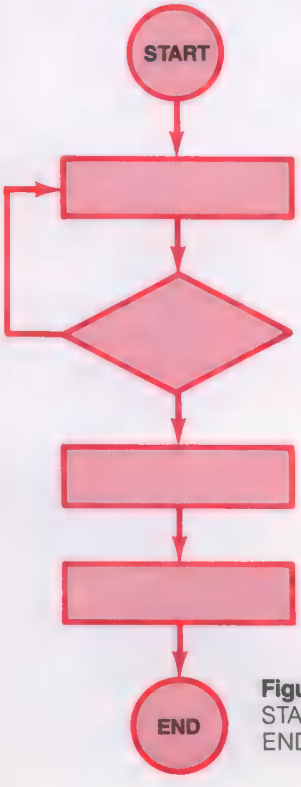


Figure 8.6 START and END symbols

In box 4 on the flowchart, we determine whether the month of your birthday is less than today's month. If so, your birthday has passed for this year, and your age may be computed (in box 5 of the flowchart) as the difference of the current year and the year of your birthday. For example, if you were born in February 1946 and we are in March 1983, your age is 1983 – 1946 = 37.

Otherwise (this is box 6 on the flowchart), your age is computed as the current year minus your birthdate's year, minus 1. For example, if you were born in June 1942 and we are in March 1983, your age is 1983 – 1942 – 1 = 40. To keep this example simple, we will not check for the day of the month. We'll add this improvement later.

The steps of the algorithm should now be clear. Let's examine the flowchart symbols.

The Symbols in the Flowchart

In a flowchart, rectangular boxes are used for computations and direct actions that do not involve a choice, such as input or display. Diamond-shaped boxes are used for tests or choices. They must always have at least two arrows coming out of them. Finally, each algorithm must have a beginning and an end. This is denoted by the labels START (or BEGIN) and END.

The symbols used in flowcharts are not uniformly standardized. Many standards have been proposed but none has gained universal acceptance. The rectangular box is always used. The diamond-shaped box, however, may be replaced by one with rounded edges, as shown in Figure 8.5. In addition, the START and END symbols can be placed in a small circle, as shown in Figure 8.6. Finally, some special symbols may be used to indicate the use of specific peripherals. For example, a PRINT operation may appear in one of two ways, as shown in Figure 8.7.

In practice you need not worry about the symbols. A flowchart is simply a way of conveniently visualizing an algorithm (especially when it contains many choices). You may even use different symbols if you wish. However, it is better to use common ones so that your programs may be more easily shared with others, and so that you can read and follow other flowcharts more easily.

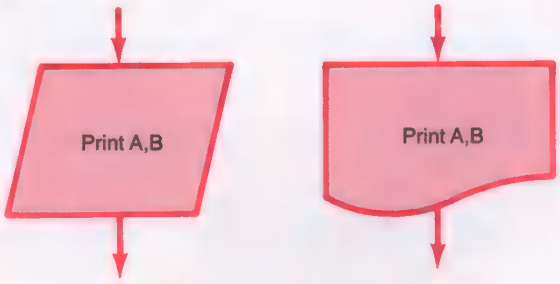


Figure 8.7 Symbols for PRINT

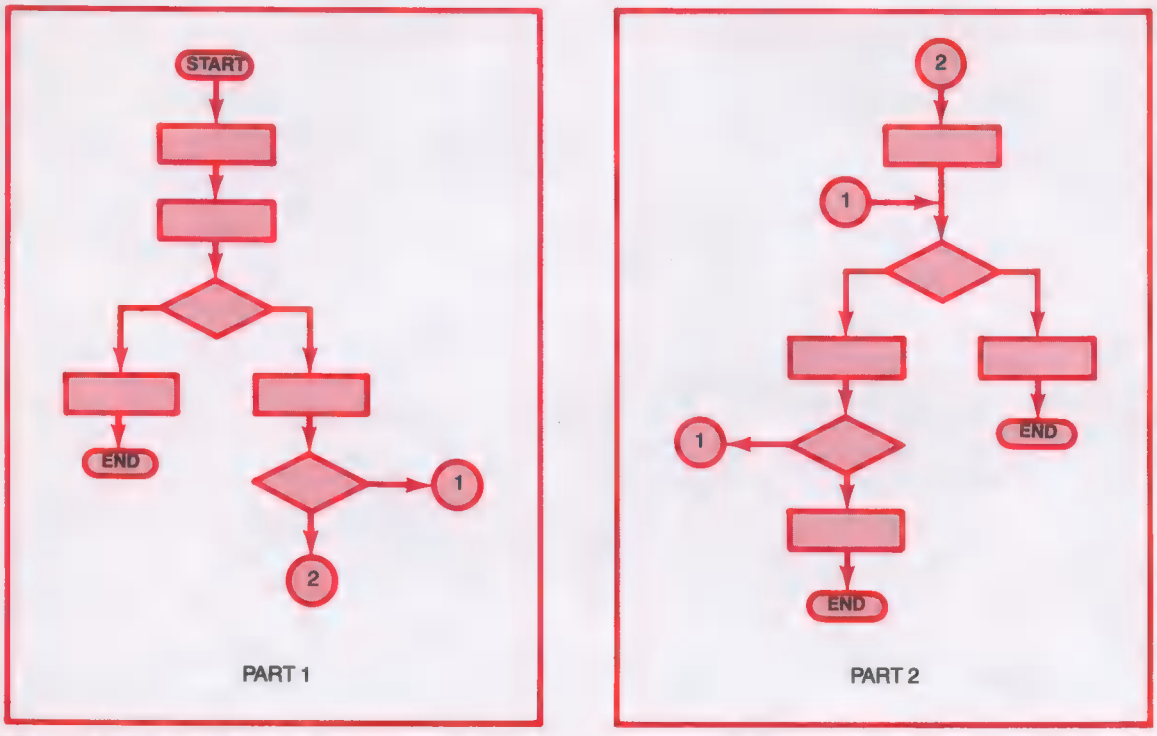


Figure 8.8 Cutting a flowchart

Cutting the Flowchart

Here is one more useful convention. If a flowchart spreads out over several pages, you can cut it into pieces. Label each cut arrow with a number or name, and make sure you have matching entry points to the flowcharts on the other pages. Figure 8.8 shows an example of using numbers to connect arrows.

Refining the Flowchart

The instructions placed in the boxes of the flowchart may be written as you please. They are not BASIC statements. When writing your flowchart for the first time, you may write instructions that are somewhat vague, such as "tell me your birthdate?"; later on, you may refine the statements contained in the boxes and design a more detailed chart that will be easier to translate into a program.

If you feel that the instructions in the boxes are sufficiently precise for you to write an equivalent program, you need not change them any further. If you feel, however, that they are too vague or complex to be translated directly into a program, then you should replace them with a sequence of more-detailed instructions.

As an example, you may recall that the flowchart in Figure 8.2 checks for the month of your birthdate, but not the day, when determining whether your birthday has already occurred this month. Let's refine it so that it checks for the month and the day. The corresponding segment of the initial (rough) flowchart appears in Figure 8.9. The new or refined flowchart is shown in Figure 8.10.

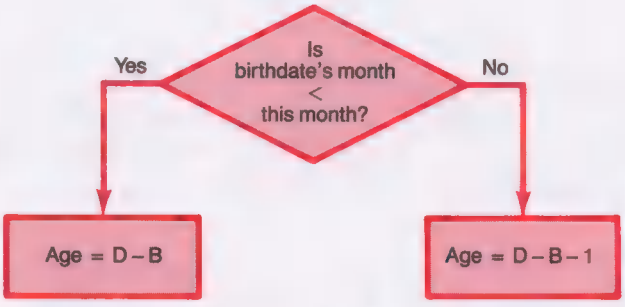


Figure 8.9 A rough algorithm

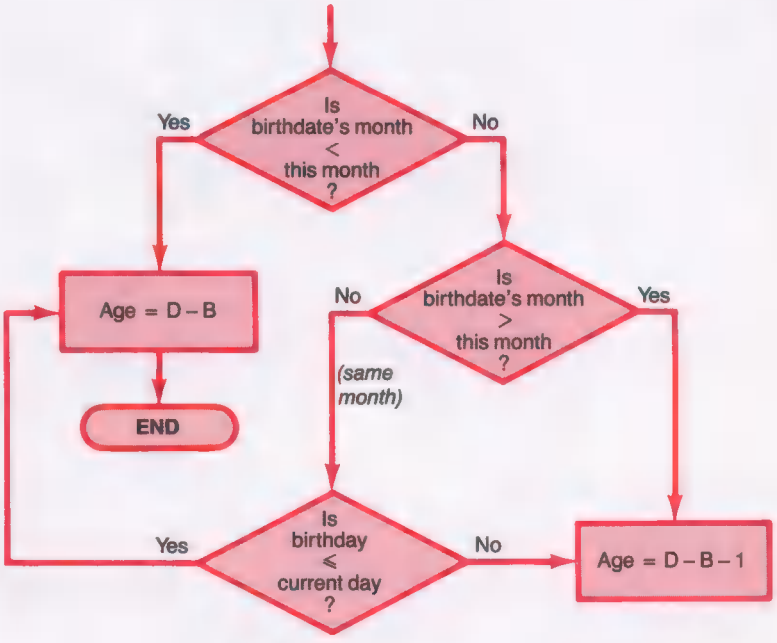


Figure 8.10 A refined flowchart

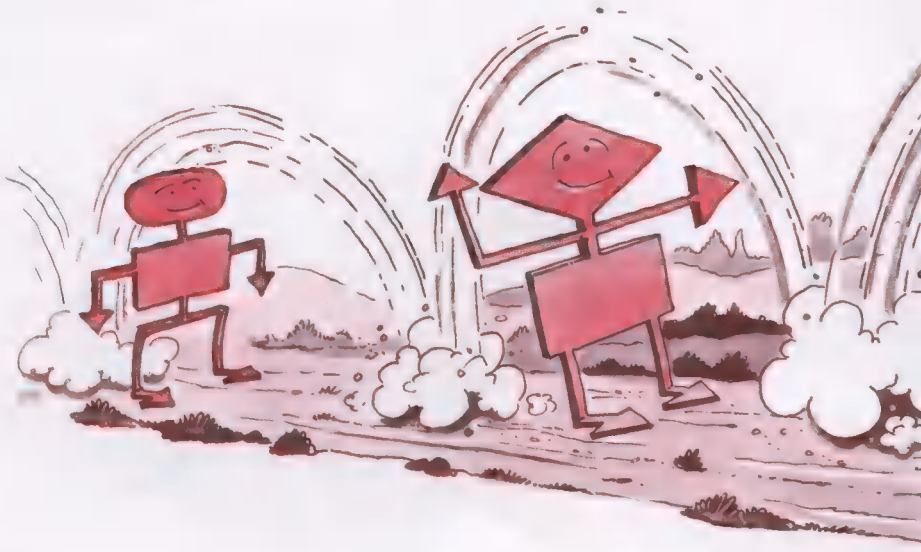
In practice most people do not write out the algorithm; they proceed directly to the flowcharting phase. This is fine. However, sometimes experienced (and not-so-experienced) programmers skip the flowcharting phase as well, and start by writing the *program* on paper. This is highly dangerous and error prone. I strongly recommend that you always draw a flowchart before writing any program. Later on as you become an expert programmer, you may be able to dispense with the detailed flowchart, and draw only a rough one.

Hand Testing

Once you have written a flowchart, test it by trying out actual examples. Make sure that the result is correct or at least appears to be correct. This is called testing *by hand,* as opposed to using the computer.

For example, go back to the age computation flowchart in Figure 8.2 and supply today's date and your own birthdate, as indicated. Does it give you the correct age? If so, things look good.

If you skip flowcharting, you'll probably run into problems



If not, there is an error. Now, try it again with different values, using birthdates that fall before and after today's date. Does it still work? If so, the algorithm is probably correct. If not, there is an error. Hand testing is a quick way to insure that there is no obvious mistake.

Having written a flowchart that seems to work, we have now accomplished all of the preliminary steps required before writing an actual program. Let us now write the program.

Coding

Writing program instructions is called *coding*. *Programming* normally refers to the entire sequence required to create a program: designing the algorithm, flowcharting, coding, debugging, and testing. Coding involves translating the contents of the flowchart boxes into program instructions expressed in a programming language—in this case, expressed in BASIC.

This is what we have learned so far: we have learned how to translate statements, formulas, tests, and conditions into BASIC instructions.

The key to easy coding is to write a detailed enough flowchart so that you can easily code each box of the flowchart into a few simple BASIC instructions. Generally, in the early stages of programming, each box in a flowchart is translated into just a few BASIC instructions, say one or two; i.e., there is a straightforward equivalence between boxes and instructions. Later as your programming skills and experience grow, you may be able to write "looser" flowcharts where each box is coded into many BASIC instructions.

Despite appearances, the coding phase is often the one that requires the least time in the program development sequence. Testing the program usually requires much longer than the actual coding. That is why it is so important to write a good flowchart—so that you can minimize errors and testing time.

When coding a program, remember to make your program accurate, clear, and readable, so that it will work quickly and can be tested or modified easily.

Make it Accurate

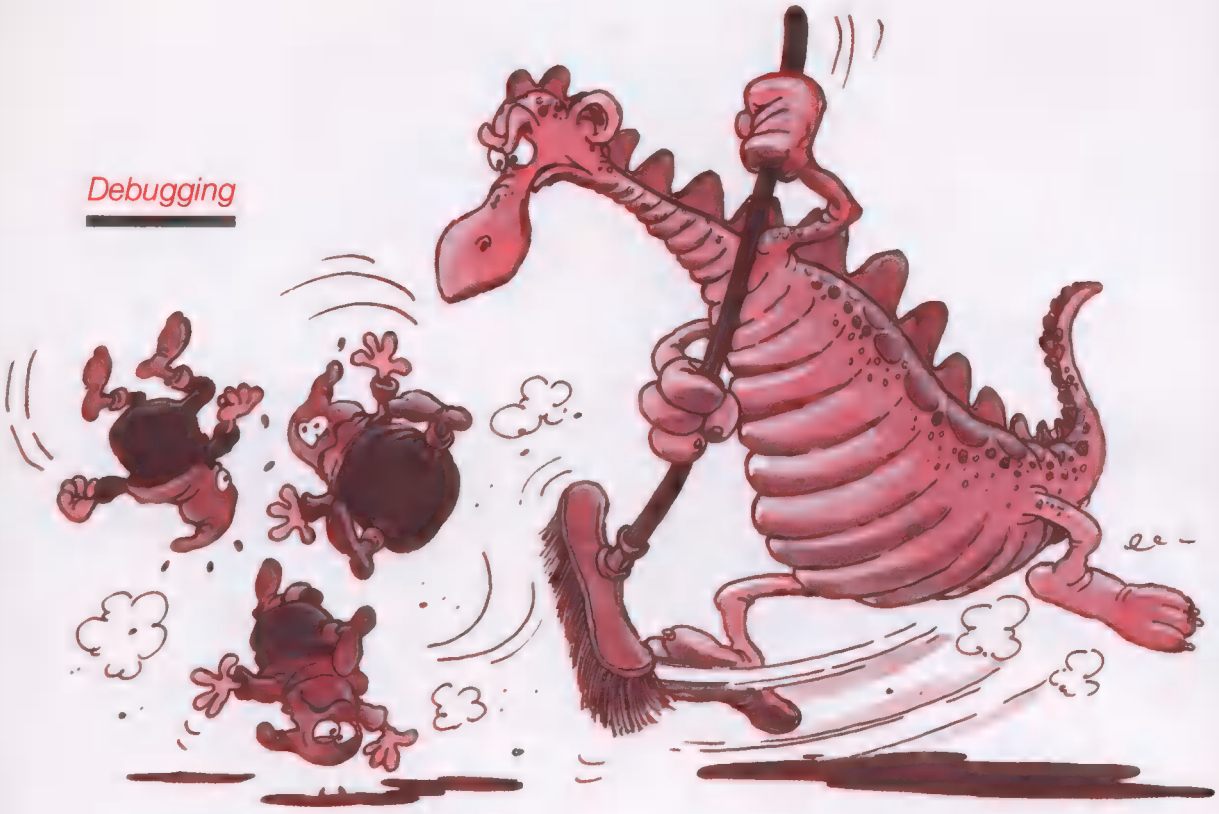
Write your program instructions with utmost care since any error in the placement of a punctuation sign or symbol will probably make the program fail.

Make it Clear

Use variable names that are easy to remember. Leave intervals or even gaps in your sequence of instruction numbers in case you might have to insert other instructions in between. Use remarks (the REM statement) liberally throughout the program to clarify what it does.

So now you have designed an algorithm, drawn a flowchart, and written the corresponding program. And you seriously expect it to work. Don't. Sorry. In the majority of cases, *programs do not work the first time.* It usually takes several attempts or lots of experience before a program of any length will run correctly. This is the topic of the next phase.

Watch out for bugs!
Make it accurate;
make it clean.



Debugging

You have coded your flowchart into a BASIC program. Your program is still on paper. You should now type it into your computer's memory, type RUN, and make sure that it works. This is called *testing* and *debugging*. Errors in a program are called *bugs*. Removing the bugs in a program is called *debugging*. Every time you find an error, you must correct it, then run the program again. Even if you have been careful and thorough in writing your program, a long program will seldom run correctly the first time. This is because it is so easy to misplace a character or even an entire instruction along the way. Even the best programmers must spend a considerable amount of time debugging their programs. So do not be surprised if you must correct your program several times before it finally runs correctly.

Fortunately, your BASIC interpreter will help you diagnose some problems. If your program contains a type of error that can be detected by the interpreter, program execution will stop after you type RUN, and the interpreter will give you the diagnostic, "ERROR — 5 IN LINE 84." The interpreter will mostly help you detect *syntax errors* (the use of illegal symbols or operations). Unfortunately, it will not help you detect the most dangerous errors, the *logical* or *design errors*. That is your responsibility. This is why you should invest the time to carefully design your flowcharts. Also, this is why every time a number is supplied to a program or generated by it,

The Interpreter helps diagnose syntax errors

you should validate that number by checking its range. In the event that your program contains a logical flaw, this technique will help you isolate the program section that contains the error.

Usually, in the case of a simple program, a few typographical errors will be detected by the BASIC interpreter. You will then correct them and your program will work. You should still make sure that it works correctly by testing it for various cases or values; your program might contain logical flaws. In most cases, however, you will determine that your program works correctly.

Practical Hints

Here is a practical hint: you should insert additional PRINT statements throughout your program to verify key values throughout. This will help you detect strange values and isolate the instructions that caused them. Here is a sample PRINT you might insert:

```
1235  PRINT "TEST FOR AVERAGE VALUE IS  "; AVERAGE
```

Then, once the program works, you can remove these extra PRINT statements. This technique is called *tracing* a variable.

As another practical hint, any time that your program stops, either on its own or because the interpreter stopped it, you should use the *direct mode* to verify the value of various variables in your program. For example, you might type:

```
PRINT AVERAGE
```

then:

```
PRINT SUM
```

to check the current values of these two variables.

The key to successful debugging is experience and a lot of prevention. Next time, spend more time on the program design and the flowchart, and you will spend less time debugging.

So your program now works correctly. You think it is correct; and you do not want to touch it any more. However, an error might be found later, or you might use the program again or share it with someone else. In order to make a program reuseable, one more step is required: you should document the program while you remember what it does.

Documentation

You have just finished designing and coding a program. You are thoroughly familiar with its operation and with what each instruction does. You will be surprised to discover how quickly you will forget what the program does and how difficult it may be to read or understand your own program later on. If you intend to reuse your program or to correct errors found at a future date, it is vital that you clarify the program promptly and completely. This means clarifying the program itself, as well as documenting everything that might require an explanation, on paper or as REMarks within the program.

Here is a summary of the techniques we have described for clarifying the program:

Use a clear layout: Separate sections with blank lines or empty statements. Use alignments or indentations for clarity. You may want to use line numbers that all have the same length. This way all program statements will be aligned vertically. In addition, every time you use a FOR . . . NEXT statement, it is a good idea to indent the block of instructions that are enclosed between the FOR and the NEXT.

Also, use blanks liberally to clarify complex instructions, in particular those containing mathematical expressions. Use parentheses to clarify the results of a computation.

Explain what you do: Use REM statements to explain formulas, tests, names, or conventions. It is also a good idea to provide a short written explanation for any methods or techniques you are using which are not obvious or are not described by PRINT statements within the program.

Clean up flowcharts: Produce one clean flowchart or set of flowcharts that correspond exactly to your program. Often, during the debugging process, last minute changes are made directly to the program. Make sure they are reflected on the original flowchart or else you may find it very difficult to change or correct your program later on.

Renumber your lines: Often, in the process of correcting the program, i.e., in the debugging phase, you will need to insert

Document your program

additional statements. Once you think your program is correct, it is a good idea to renumber the lines so that all line numbers are spaced regularly. This will facilitate later changes to the program. A special line-numbering program, which will renumber an entire program, is available for the Atari. This is a convenience, not a requirement.

Summary

In this chapter, we have described the five steps to a finished program: designing, flowcharting, coding, debugging, and documenting. Let us review them.

Each program requires designing an algorithm. The algorithm must be designed at least mentally if not on paper. The algorithm may be sketched as a series of formulas or notes describing the essential steps.

The next step is designing the flowchart that describes the complete sequence of events. Consider it as a mandatory step for any program that involves more than a few lines. Remember, the more carefully you design your flowchart, the better the chance that your program will be correct.

The next step is coding. The flowchart is translated into BASIC instructions. Practice will speed-up this phase considerably. In fact, the coding phase quickly becomes the shortest phase.

Then comes testing and debugging. This phase is always required and is often the longest phase. Each program must be carefully checked out.

Finally, the quality of the documentation will facilitate or impede the later use of, and changes to, the program.

Exercises

8-1: Describe the five phases of program development.

8-2: What is the difference between coding and programming?

8-3: What is the purpose of debugging?

8-4: How do you trace a variable?

8-5: Why renumber a program after making many changes?

8-6: What is a flowchart?

8-7: Write a flowchart to start your car or operate an appliance.

8-8: What are the advantages of a clearly-written program?

8-9: Describe the techniques that can be used to clarify a program.

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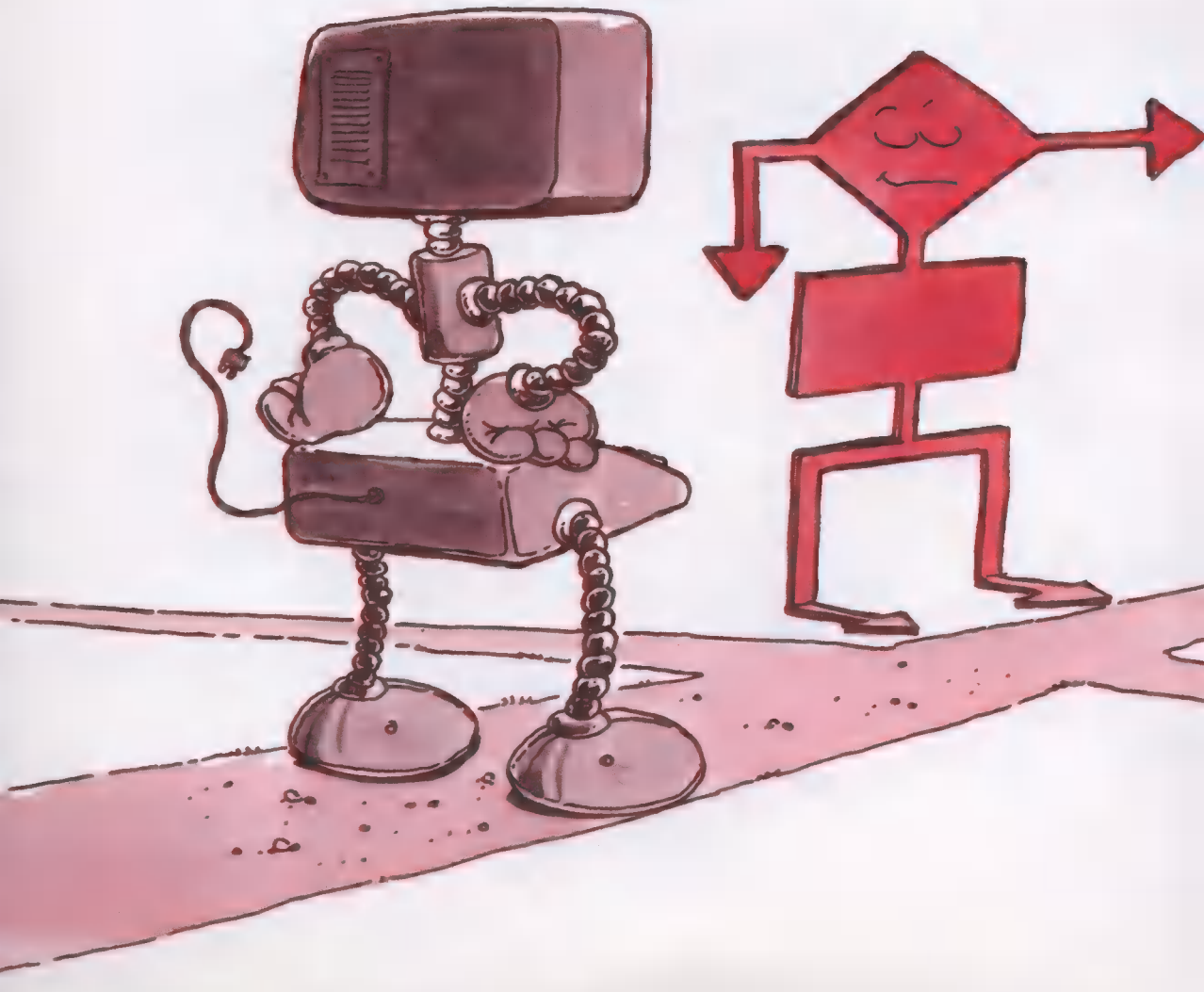


se Study: onversion

9

We will now develop a complete program and describe each step in turn. Here is the problem to be solved:

We need to write a program that will automatically convert a weight expressed in ounces into its equivalent value in grams. This program should either convert a number typed at the keyboard, or print a weight conversion table for those numbers between two specified values.

Designing the Algorithm

The rough sequence of steps that we will follow to solve this problem is quite straightforward: We will ask the user what he or she wants (a single conversion or a table of values) and then perform the action requested. This is our rough algorithm. Let us refine it.

One ounce equals 28.35 grams. The conversion from ounces to grams is therefore accomplished by the following formula:

$$W_{grams} = W_{ounces} \times 28.35$$

or, in short:

$$W_g = W_{oz} \times 28.35$$

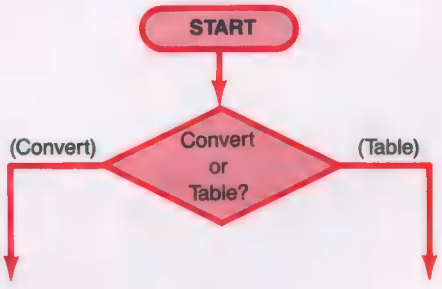
Here is the basic algorithm:

- Specify either single conversion or table
- If conversion, request weight in ounces
- Convert to grams (using the formula above) and display result
- END
- If table, request maximum weight in ounces
- Convert to grams and display results up to the limit
- END

In practice, there is no need to write out the algorithm, as long as you prepare a flowchart.

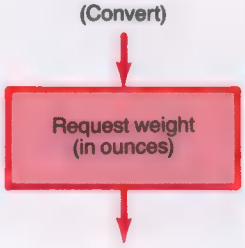
Flowcharting

In preparing the flowchart, we must first know whether the user wants the program to perform a single conversion or display a table of values. Here is the corresponding flowchart element:

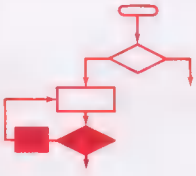


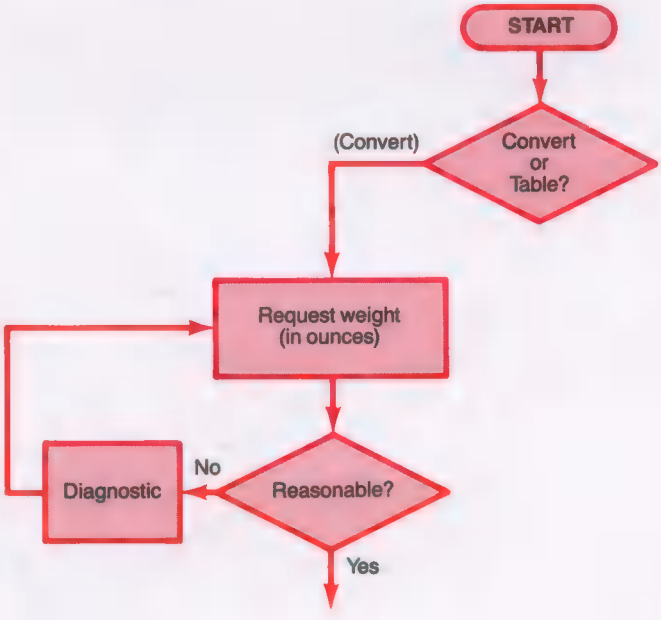
This is a decision box, with two possible outcomes (i.e., branches): CONVERT and TABLE.

Let's first examine CONVERT: The user wants to convert a single weight from ounces to grams. We must request the value of the weight. Here is the corresponding flowchart entry:



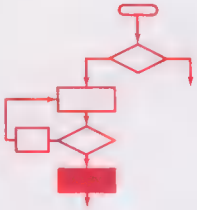
We could now convert this value into grams. However, let's refine the flowchart immediately. As a precaution, we will validate the value supplied by the user, by checking whether it is reasonable or not. Here is the way our flowchart looks with this validation added:

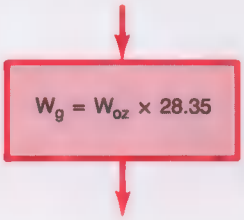




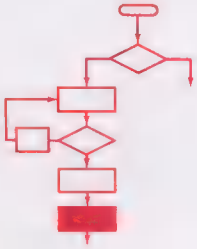
Note that we have added a box to check whether the input is reasonable. If the input is reasonable, we proceed. If not, a diagnostic, such as "UNREASONABLE INPUT, TRY AGAIN" is issued, and the program requests another value for the weight.

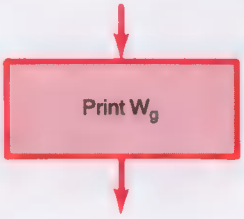
We now have a validated value for the weight. Let's convert it into grams. This is accomplished by the following:



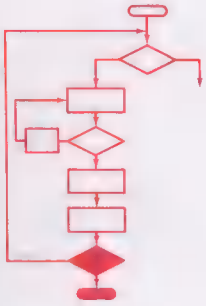


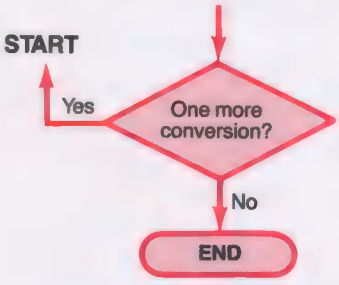
We can now display the results. This is accomplished by the following box:



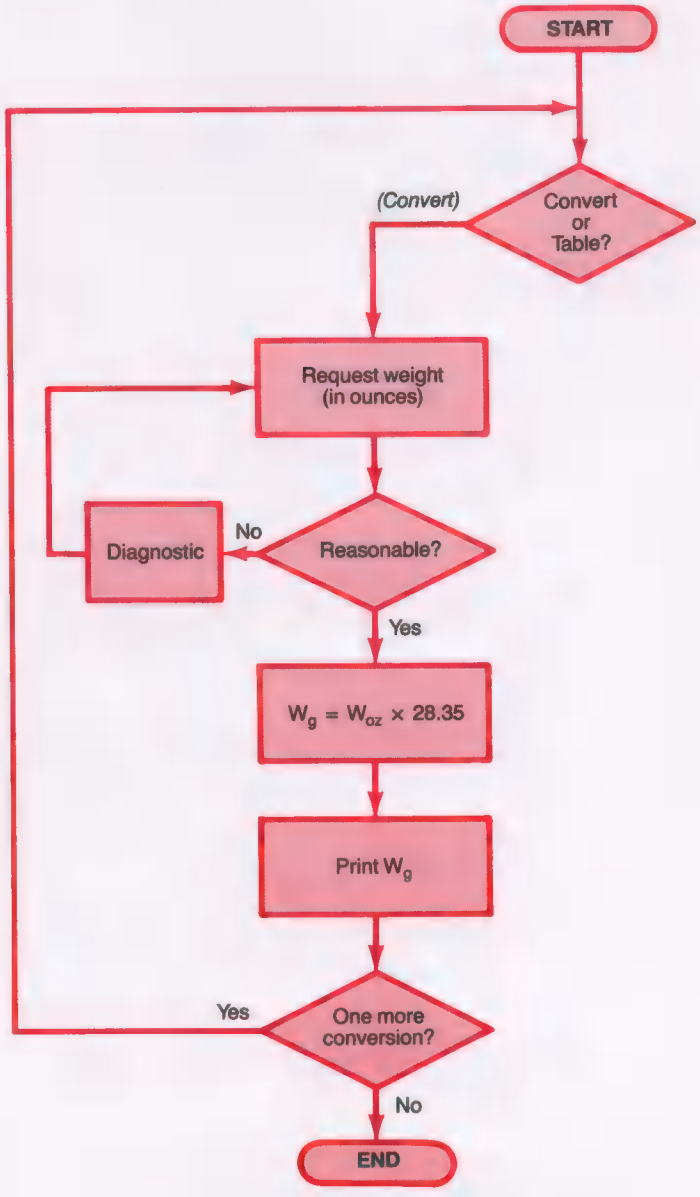


The single conversion is now done. We could end this part of the flowchart here. However, let's add a convenience feature and ask the user whether he or she wants to do another conversion. This is accomplished by the following box:

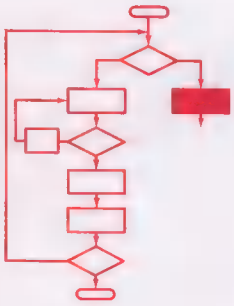




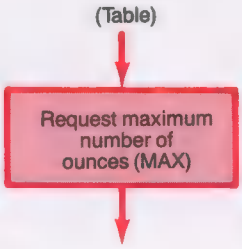
The START symbol on the left arrow indicates that this arrow will be connected back to the beginning of the flowchart. At this point, our flowchart looks like this:

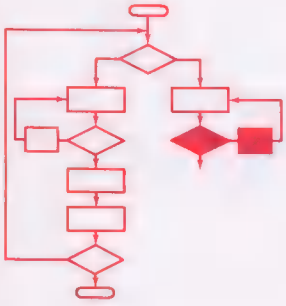


Let us now go back to our first decision box and examine what happens when the user wants to display a table of values. This is the TABLE option at the top of the flowchart.

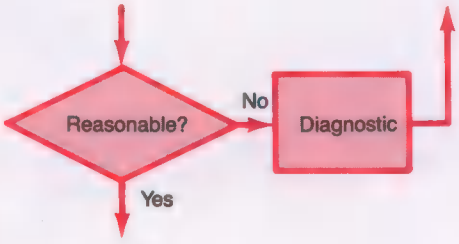


We must know the maximum value to be converted. This is accomplished by the following box:



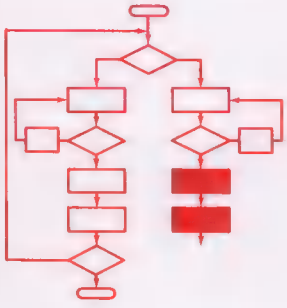


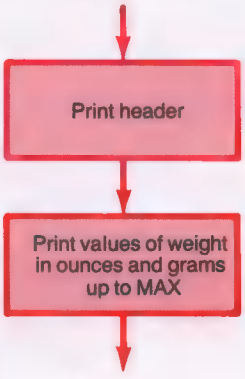
Again, for safety, we will check whether this number is reasonable:



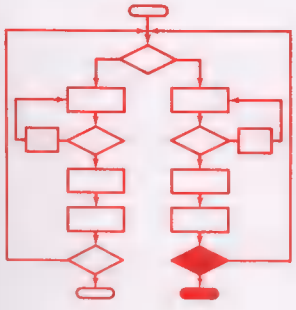
As before, the program will not proceed until a reasonable value of MAX is supplied by the user.

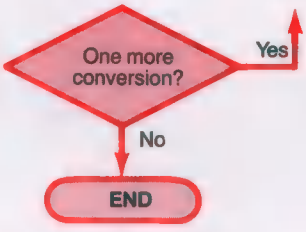
Once a reasonable value is supplied, we can proceed and display a table that converts ounces to grams, up to the desired limit:





Finally, let's add the same convenience feature that we used in the single conversion case and ask the user whether he or she would like to perform one more conversion:





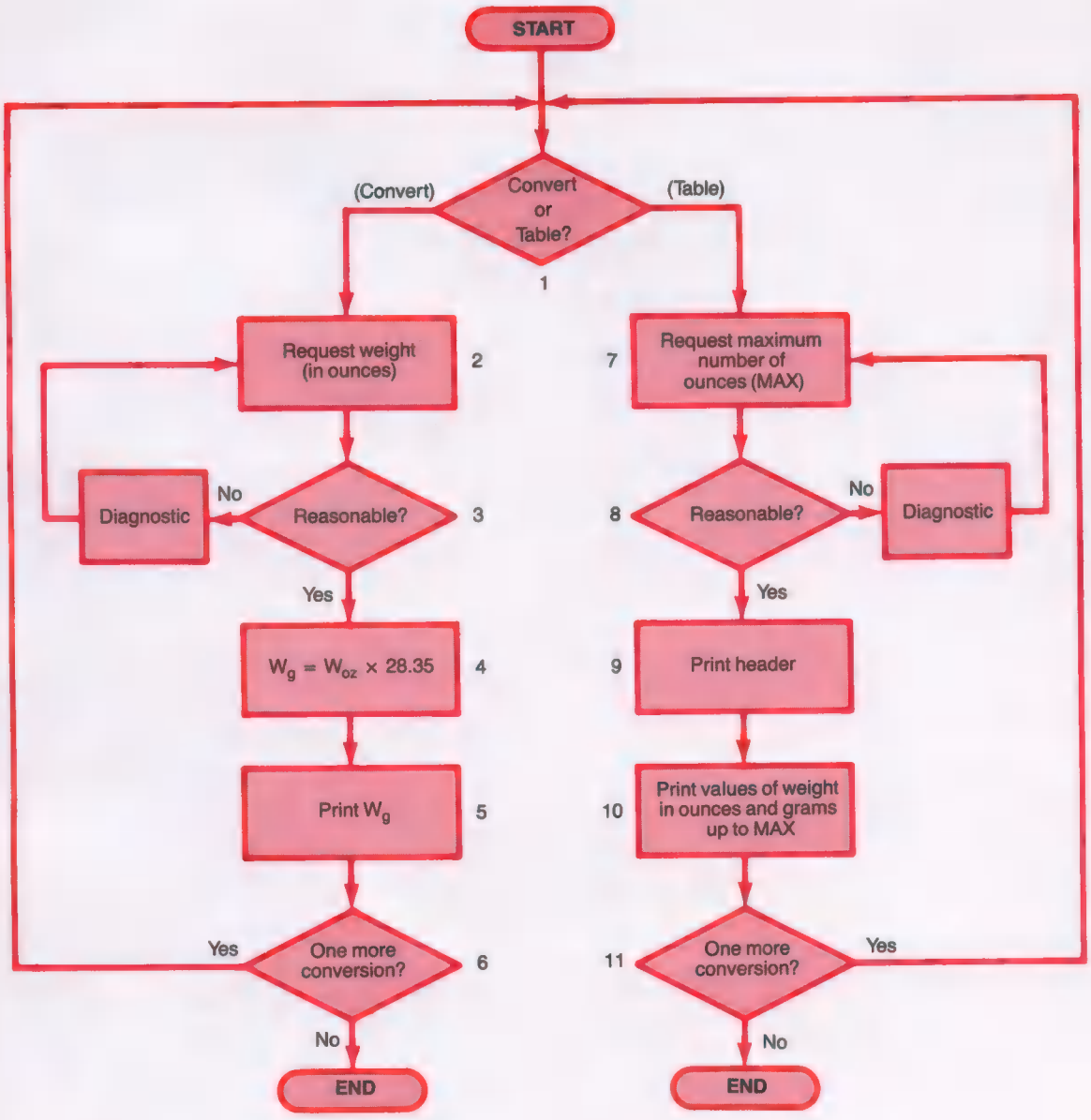


Figure 9.1
Weight Conversion flowchart

Figure 9.1 shows the complete flowchart. This flowchart is typical. The contents of the boxes are somewhat "loosely" written. Some boxes in the flowchart will be coded into just one or two BASIC instructions, while others will require many more. However, it is the sequence that counts. The fact that some boxes may be more detailed than others does not matter. Remember that the flowchart sequence must be exact, but the details may be written in any manner that is convenient for you. There is no need to spend a lot of time optimizing the contents of the boxes, as long as you feel you can code from it in a straightforward manner.

The flowchart must simply be clear and easy to read. A clear, well-organized flowchart improves your chances of writing a correct program.

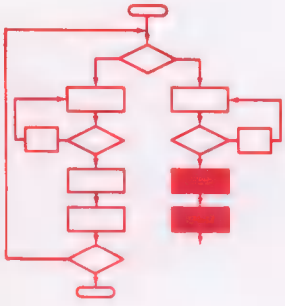
For completeness, here are some refinements or alternatives you might consider:

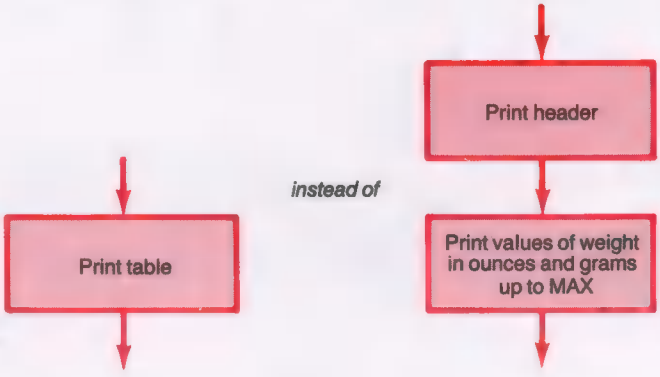
- You could explain in detail the way you will check the weight for "reasonableness." (Here we will simply check that WOZ is a positive number.)
- You could be more explicit about the diagnostic and about much of the dialogue.

In general, the advice is: *keep it simple.* Do just enough so that:

1. The sequence of steps is correct and complete.
2. You understand each box and know roughly how to convert it into program instructions.

The simpler the contents of the boxes, the clearer the flowchart. The more detailed the contents of the boxes, the easier the coding. Applying this advice, we could simplify the flowchart by writing:





Both options are correct. Use the one you feel most comfortable with. Here, I decided to hint at the programming steps involved and therefore I made the contents of the box more explicit.

You can always rewrite the contents of a box, or for that matter any part of your flowchart, on a separate piece of paper to facilitate the coding, or to try out an alternative.

Now that we have a flowchart, let's try it out by hand with actual numbers, to make sure it works. This hand-checking process is obvious, so let's proceed.

Coding

We will now write a program that corresponds to our flowchart. Let's code each box of the flowchart into the corresponding BASIC instructions.

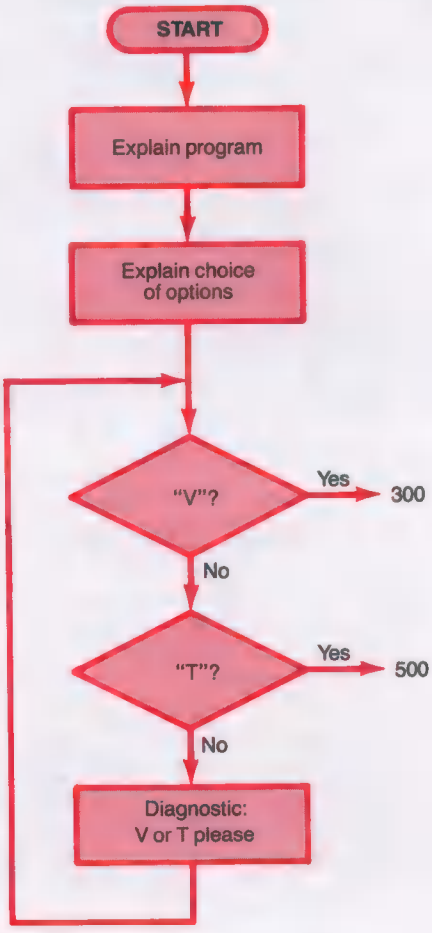
Here is box 1 of the flowchart:

Here are the corresponding program instructions:

```
90   REM * ■ ■ CONVERSION OF OUNCES TO GRAMS * ■ *
100  DIM  CHOICE$(1), AGAIN$(1)
110  REM THIS PROGRAM PERFORMS EITHER A DIRECT
       CONVERSION
120  REM OR PRINTS A TABLE OF VALUES
130  REM FIRST, SPECIFY THE CONVERSION MODE:
       DIRECT OR TABLE
140  PRINT "I WILL CONVERT OUNCES TO GRAMS"
150  PRINT "IF YOU WANT TO CONVERT A VALUE DIRECTLY,
       TYPE V."
160  PRINT "IF YOU WANT TO PRINT A TABLE OF VALUES,
       TYPE T."
170  PRINT "YOUR CHOICE [V OR T]";
180  INPUT CHOICE$
190  IF CHOICE$ = "V" THEN GOTO 300
200  REM LABEL 300 IS VALUE CONVERSION
210  IF CHOICE$ = "T" THEN GOTO 500
220  REM LABEL 500 IS TABLE CONVERSION
230  REM IF THE CHARACTER WAS NOT V OR T, THE INPUT
       IS INVALID
240  PRINT "V OR T PLEASE: ";
250  GOTO 170
```

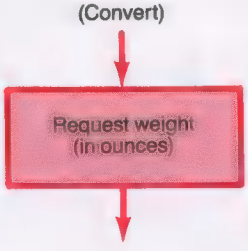
As you become more experienced, you may be able to go directly from box 1 of the flowchart to the corresponding program instructions. However, at the beginning, you will need to write down the detailed version of the flowchart first.

Here is the detailed version of box 1:



Looking at this detailed version, note how closely the flowchart corresponds with the BASIC instructions. In addition, note that we have introduced a *validity test* for CHOICE$. We aren't going to simply assume that the user will cooperate and type "V" or "T". Check it. **Remember:** every time you request an input, you should validate it.

The rest is simpler. Let's convert box 2:



The corresponding instructions are:

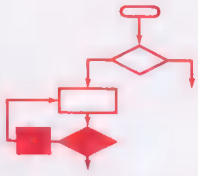
```
300  REM ■ ■ ■ VALUE CONVERSION * ■ ■
310  PRINT "TYPE THE WEIGHT IN OUNCES...";
320  INPUT WOZ
```

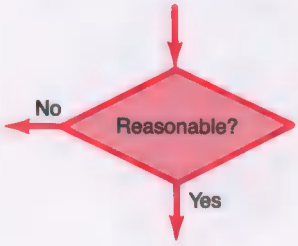
As an aside, we could also write:

```
310  PRINT "TYPE THE WEIGHT IN OUNCES..."; : INPUT WOZ
```

Here, I decided to separate the PRINT and INPUT instructions; thus making it easier to show how the program lines correspond with the flowchart. You may, however, use either form.

Let's proceed. Here is box 3:





Here is its program equivalent:

```
330  IF WOZ < 0 THEN GOTO 310
340  REM WEIGHT MUST BE POSITIVE
350  REM WE COULD ADD EXPLICIT MESSAGE HERE
```

The equivalent of box 4 is:

```
360  WG = WOZ ■ 28.35
```

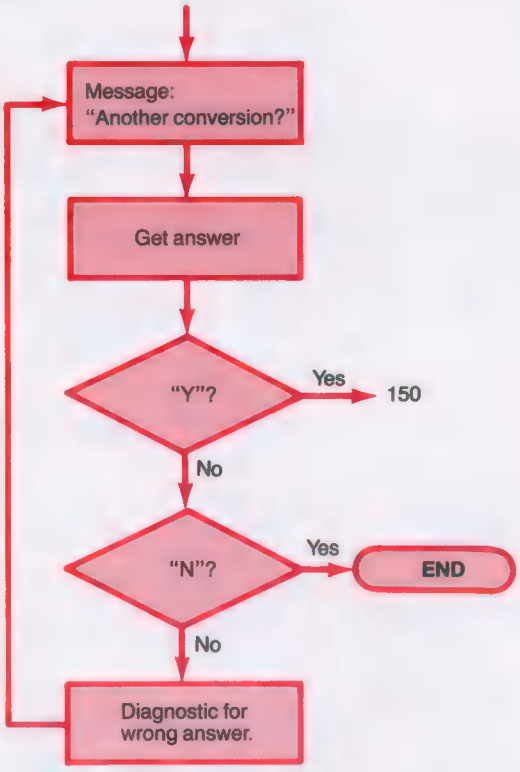
And for box 5:

```
370  PRINT WOZ; "OUNCES ARE EQUIVALENT TO"; WG; "GRAMS"
```

And for box 6:

```
410  PRINT "DO YOU WANT ANOTHER CONVERSION? Y FOR YES,
       N FOR NO:"
420  INPUT AGAIN$
430  IF AGAIN$ = "Y" THEN GOTO 150
440  IF AGAIN$ = "N" THEN END
450  REM INPUT WAS NOT Y OR N. TELL USER
460  PRINT "Y OR N PLEASE"
470  GOTO 380
```

If the above is not clear to you, here is the equivalent detailed flowchart:



Let's now look at the right part of the flowchart in Figure 9.1. Here is the equivalent of box 7:

```
520  PRINT "I WILL DISPLAY A CONVERSION TABLE"
530  PRINT "OF OUNCES TO GRAMS"
540  PRINT "TELL ME THE MAXIMUM NUMBER OF OUNCES:";
550  INPUT MAX
```

And for box 8:

```
560  REM MAX MUST BE EQUAL TO OR GREATER THAN 1.
       IF NOT, IT IS REJECTED
570  IF MAX < 1 THEN GOTO 540
```

For clarity, let's skip a line on the display, before we print the table:

```
580  PRINT
```

Remember: that's an empty PRINT. It displays a blank line. Now here is the equivalent of box 9:

```
590  PRINT "OUNCES",  "GRAMS"
```

Note that we use a comma rather than a semicolon for a pleasant spacing of the columns.

And here is box 10:

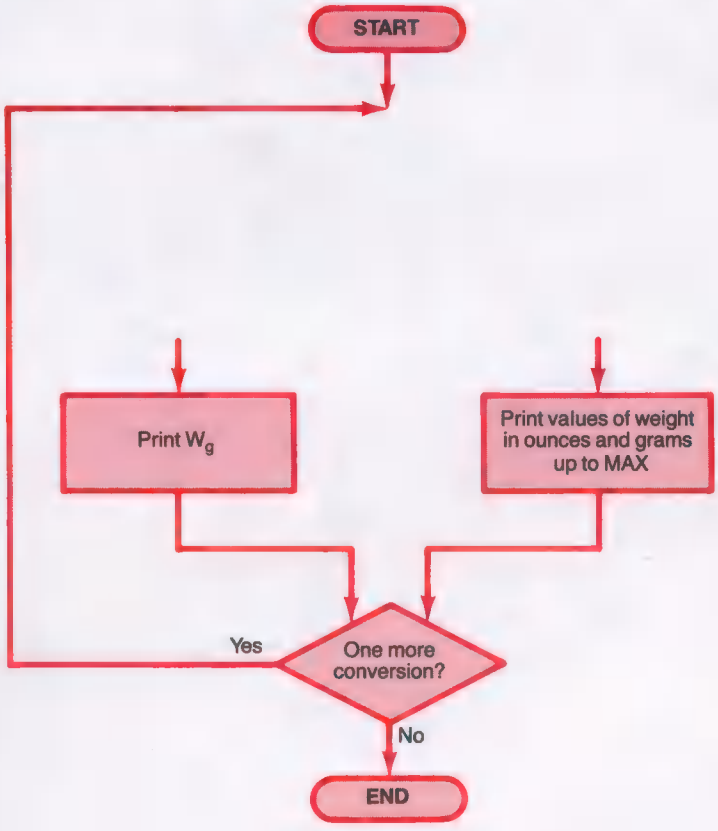
```
600  I = 1
610  PRINT I,   I * 28.35
620  I = I + 1
630  IF I<= MAX  THEN  GOTO  610
```

Finally, here is box 11:

```
650  GOTO  380
```

Box 11 is the same as box 6, so we can simplify our program by jumping (GOTO) to the instructions for box 6.

Here is the corresponding (corrected) flowchart:



The complete program is shown on the following page.

```
90   REM * * * CONVERSION OF OUNCES TO GRAMS * * *
100  DIM CHOICE$(1), AGAIN$(1)
110  REM THIS PROGRAM PERFORMS EITHER A DIRECT CONVERSION
120  REM OR PRINTS A TABLE OF VALUES
130  REM FIRST, SPECIFY THE CONVERSION MODE: DIRECT OR TABLE
140  PRINT "I WILL CONVERT OUNCES TO GRAMS"
150  PRINT "IF YOU WANT TO CONVERT A VALUE DIRECTLY, TYPE V."
160  PRINT "IF YOU WANT TO PRINT A TABLE OF VALUES, TYPE T."
170  PRINT "YOUR CHOICE [V OR T]";
180  INPUT CHOICE$
190  IF CHOICE$ = "V" THEN GOTO 300
200  REM LABEL 300 IS VALUE CONVERSION
210  IF CHOICE$ = "T" THEN GOTO 500
220  REM LABEL 500 IS TABLE CONVERSION
230  REM IF THE CHARACTER WAS NOT V OR T, THE INPUT IS INVALID
240  PRINT "V OR T PLEASE: ";
250  GOTO 170
260  REM
270  REM
300  REM * * * VALUE CONVERSION * * *
310  PRINT "TYPE THE WEIGHT IN OUNCES . . .";
320  INPUT WOZ
330  IF WOZ < 0 THEN GOTO 310
340  REM WEIGHT MUST BE POSITIVE
350  REM WE COULD ADD EXPLICIT MESSAGE HERE
360  WG = WOZ * 28.35
370  PRINT WOZ;  "OUNCES ARE EQUIVALENT TO ";  WG;  "GRAMS "
380  REM
390  REM * * * EXIT MODULE * * *
400  PRINT
410  PRINT "DO YOU WANT ANOTHER CONVERSION? Y FOR YES, N FOR NO:
420  INPUT AGAIN$
430  IF AGAIN$ = "Y" THEN GOTO 150
440  IF AGAIN$ = "N" THEN END
450  REM INPUT WAS NOT Y OR N. TELL USER
460  PRINT "Y OR N PLEASE"
470  GOTO 380
480  REM
490  REM
500  REM * * * TABLE CONVERSION * * *
510  REM REQUEST UPPER LIMIT
520  PRINT "I WILL DISPLAY A CONVERSION TABLE"
530  PRINT "OF OUNCES TO GRAMS"
540  PRINT "TELL ME THE MAXIMUM NUMBER OF OUNCES:";
550  INPUT MAX
560  REM MAX MUST BE EQUAL TO OR GREATER THAN 1. IF NOT, IT IS REJECTED
570  IF MAX < 1 THEN GOTO 540
580  PRINT
590  PRINT "OUNCES",  "GRAMS"
600  I = 1
610  PRINT I, I * 28.35
620  I = I + 1
630  IF I <= MAX THEN GOTO 610
640  REM I IS NOW > MAX. THIS IS END OF TABLE
650  GOTO 380
660  END
```

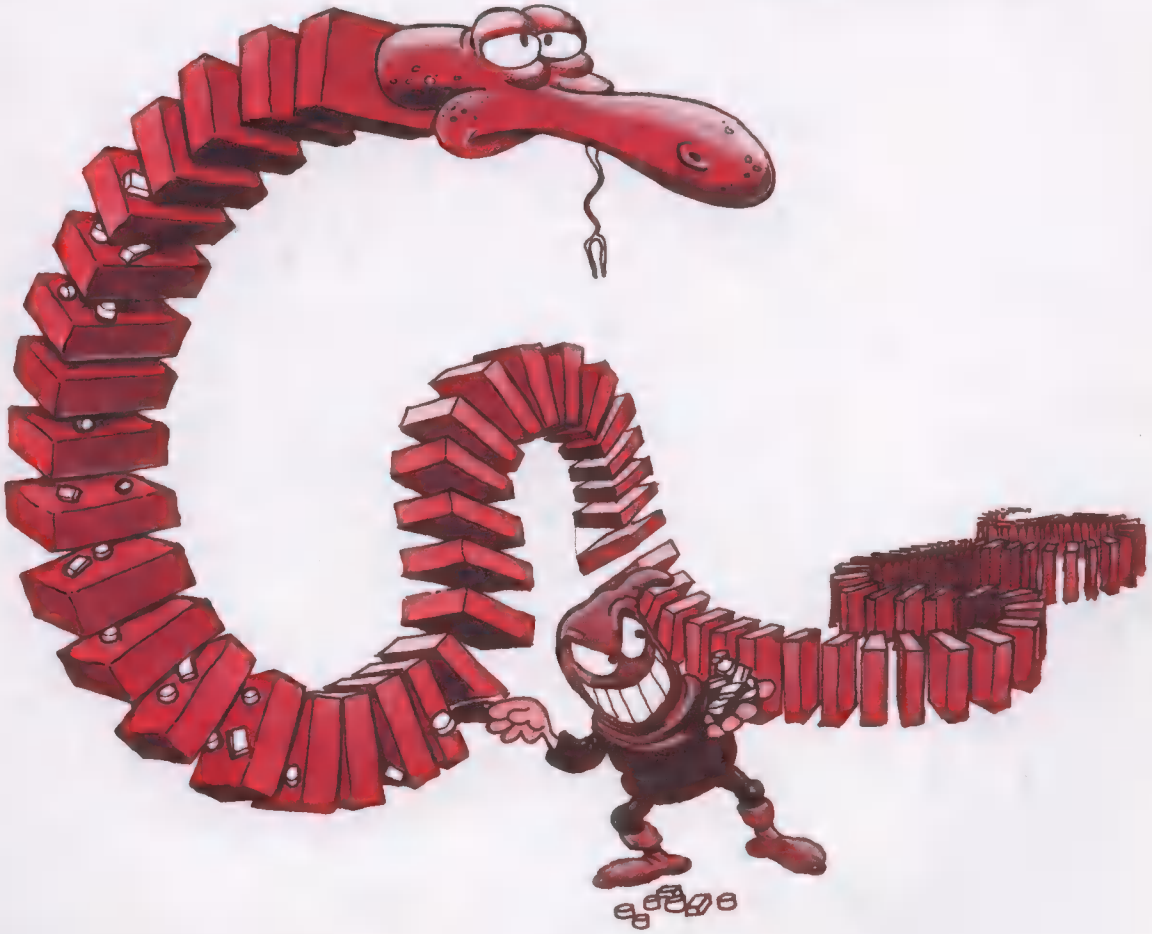
Some improvements have been added. For example, many REMs have been added for clarity (see instructions 260, 270, 300, 380, 390, 480, 490, 500).

Other improvements could be made. For example, the instructions 600 to 630 could be replaced with a FOR . . . NEXT statement. This might improve readability, but it is hardly worth the trouble.

Remember: any change you make to a working program may introduce new bugs. Change your program only if there is a clear benefit.

We now have a complete program. Let's try it out.

Remember: any change you make may introduce new bugs!



Testing

Let's run the program. Here is a sample run:

```
I WILL CONVERT OUNCES TO GRAMS
IF YOU WANT TO CONVERT A VALUE DIRECTLY, TYPE V.
IF YOU WANT TO PRINT A TABLE OF VALUES, TYPE T.
YOUR CHOICE [V OR T]? V
TYPE THE WEIGHT IN OUNCES...? 3
 3 OUNCES ARE EQUIVALENT TO 85.05 GRAMS
```

Here is another one:

```
DO YOU WANT ANOTHER CONVERSION? Y FOR YES, N FOR NO:? Y
IF YOU WANT TO CONVERT A VALUE DIRECTLY, TYPE V.
IF YOU WANT TO PRINT A TABLE OF VALUES, TYPE T.
YOUR CHOICE [V OR T]? T
I WILL DISPLAY A CONVERSION TABLE
OF OUNCES TO GRAMS
TELL ME THE MAXIMUM NUMBER OF OUNCES:? 4

OUNCES      GRAMS
  1          28.35
  2          56.7
  3          85.05
  4          113.4
```

Our program seems to work for a single conversion as well as a table.

Let's try to fool it:

```
DO YOU WANT ANOTHER CONVERSION? Y FOR YES, N FOR NO:? Y
IF YOU WANT TO CONVERT A VALUE DIRECTLY, TYPE V.
IF YOU WANT TO PRINT A TABLE OF VALUES, TYPE T.
YOUR CHOICE [V OR T]? D
V OR T PLEASE: YOUR CHOICE [V OR T]? V
TYPE THE WEIGHT IN OUNCES. . .? 7
 7 OUNCES ARE EQUIVALENT TO 198.45 GRAMS
```

Let's try the repeat option:

```
DO YOU WANT ANOTHER CONVERSION? Y FOR YES, N FOR NO:? Y
IF YOU WANT TO CONVERT A VALUE DIRECTLY, TYPE V.
IF YOU WANT TO PRINT A TABLE OF VALUES, TYPE T.
YOUR CHOICE [V OR T]? V
TYPE THE WEIGHT IN OUNCES. . .? 85
 85 OUNCES ARE EQUIVALENT TO 2409.75 GRAMS

DO YOU WANT ANOTHER CONVERSION? Y FOR YES, N FOR NO:? Y
IF YOU WANT TO CONVERT A VALUE DIRECTLY, TYPE V.
IF YOU WANT TO PRINT A TABLE OF VALUES, TYPE T.
YOUR CHOICE [V OR T]? V
TYPE THE WEIGHT IN OUNCES. . .? 2.5
 2.5 OUNCES ARE EQUIVALENT TO 70.875 GRAMS

DO YOU WANT ANOTHER CONVERSION? Y FOR YES, N FOR NO:? Y
IF YOU WANT TO CONVERT A VALUE DIRECTLY, TYPE V.
IF YOU WANT TO PRINT A TABLE OF VALUES, TYPE T.
YOUR CHOICE [V OR T]? V
TYPE THE WEIGHT IN OUNCES. . .? 3.1
 3.1 OUNCES ARE EQUIVALENT TO 87.885 GRAMS
```

Let's try and fool it again:

```
DO YOU WANT ANOTHER CONVERSION? Y FOR YES, N FOR NO:? Y
IF YOU WANT TO CONVERT A VALUE DIRECTLY, TYPE V.
IF YOU WANT TO PRINT A TABLE OF VALUES, TYPE T.
YOUR CHOICE [V OR T]? V
TYPE THE WEIGHT IN OUNCES. . .? -5
TYPE THE WEIGHT IN OUNCES. . .? □
```

Well, it seems to work. But you should really try it several more times before you are completely satisfied with it.

In this case, we have been very careful—and very lucky. Our program worked right the first time.

Summary

In this chapter we have illustrated the complete sequence involved in writing a program that solves a given problem. You should now close this book, write your own flowchart, and convert it into a working program.

The key to successful programming is practice.

Exercises

9-1: Add to this program the option of converting grams to ounces.

9-2: Expand the program to include distance conversion.

1 meter = 39.37079 inches.

1 km = 0.62138 mile.

1 inch = 25.3995 mm

1 foot = 30.479 cm

1 yard = 0.91438 m

1 mile = 1609.3149 m

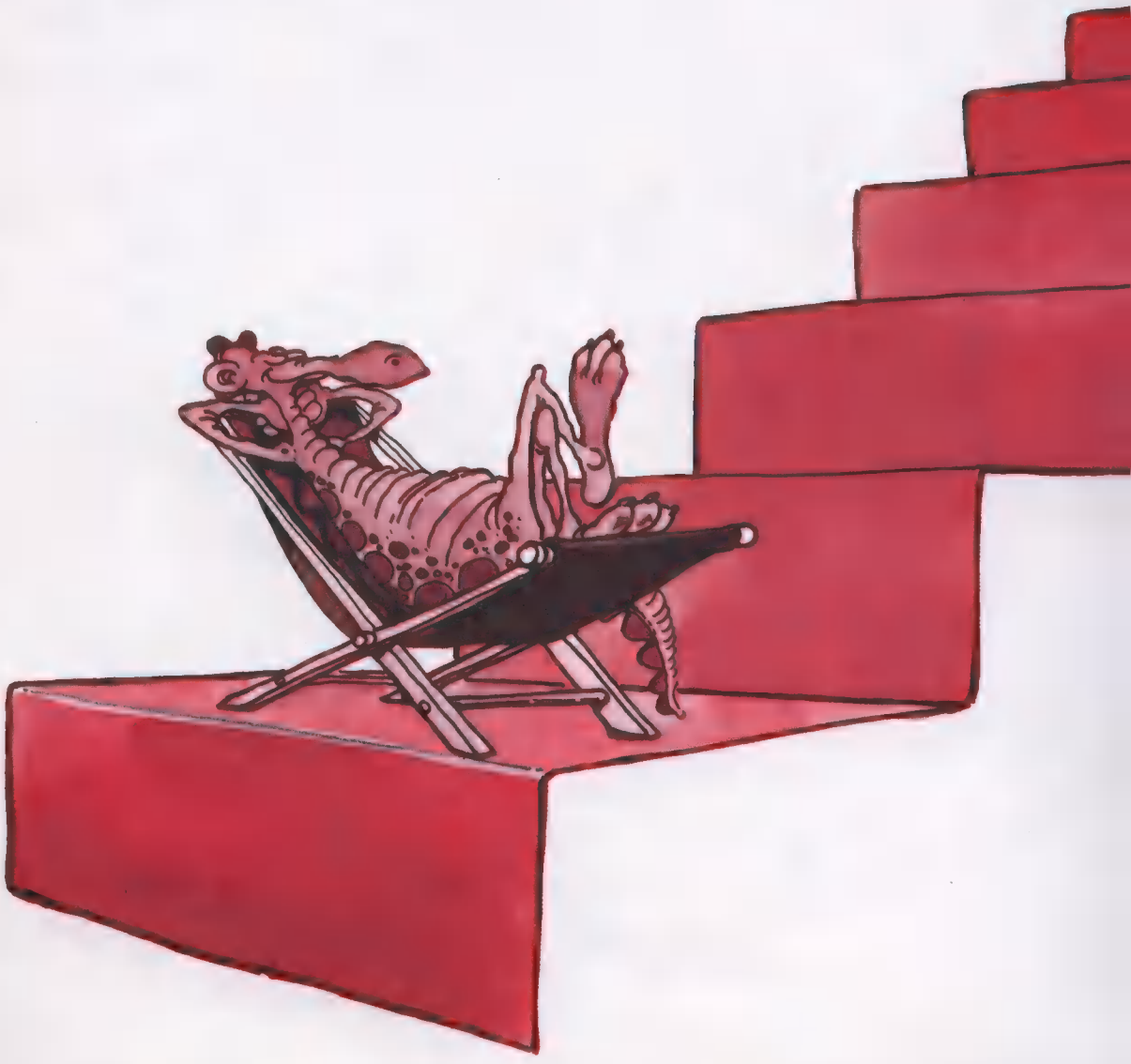
9-3: Expand the program to include temperature conversion.

$C = (F - 32) \times 5/9$

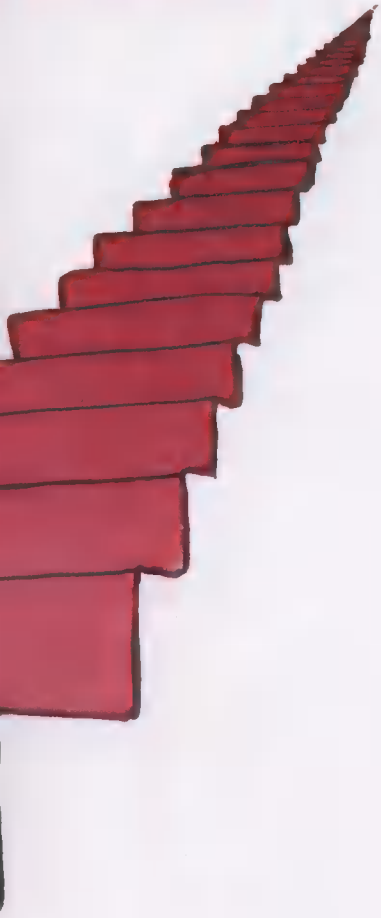
$F = (9/5) \times C - 32$

9-4: Suggest additional ways to improve or clarify our final program.

The Ne



xt Step



10

You have now learned how to write your own BASIC programs. In this chapter, we will examine the next step you can take towards improving your programming skills. We will review what you can do with BASIC, and then describe the additional skills and techniques that can help you more easily write complex programs.

What You Can Do with BASIC

You can write a BASIC program to automate most tasks, unless they require very precise mathematical computations, complex decision-making, or a very fast response (such as real-time process control). You will find that BASIC is well-suited to simple business applications, such as data processing, mailing lists, and common financial computations. With extensions to the language, BASIC also lends itself well to graphics and games.

Other typical application areas for BASIC include computer-assisted education, personal and business record-keeping, mathematical and technical computations with a limited degree of precision, and many more. Applications are generally limited mostly by one's programming skills.

With the knowledge you have acquired so far, you should be able to write a wide variety of BASIC programs. However, as you progress, you will want to improve your skills and use more powerful and convenient programming tools. That is the topic of the next sections.

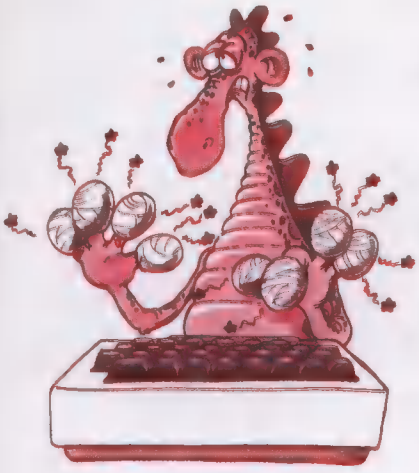
Improving Your Skills

You can take three essential steps towards increasing your skills in BASIC:

1. Gain more practice
2. Obtain a better knowledge of the complete resources of Atari BASIC
3. Learn additional programming techniques.

Let us review each step in turn.

Improve your skills



Practice more

More Practice

The key to programming effectiveness is practice: write as many programs as possible, and get them to work. Develop good programming habits by following all the recommendations presented in this book. If your programs work consistently after just a few tries, you may be well on your way to becoming a disciplined and effective programmer. If they do not, watch your habits, or perhaps read parts of this book again, and then practice some more. **Remember:** there is no way you can become a good programmer unless you write many programs. This book will get you started, but it can never be a substitute for actual experience.

Specific BASIC Features

Your Atari BASIC interpreter provides specific capabilities, including statements, commands, shorthand facilities, extensions to "standard BASIC" (such as graphics and sound), and an operating environment (including disk or cassette storage commands, file facilities, an editor program, and more). You can enhance your programming ability by learning these additional features and facilities. In the next section we will describe the additional BASIC statements found in Atari BASIC. Facilities, such as graphics, sound, and files are specific to your computer and your interpreter. You will gain by learning about them.

Additional Techniques

Once you develop longer programs (say, longer than one page), you will want to learn the usual techniques for solving common problems, such as ordering items, sorting them, formatting data, filing, and creating data structures. These topics are covered in programming books.

More BASIC

Atari BASIC interpreter offers a fairly "standardized" set of facilities, plus many extensions that are specific to the interpreter. The facilities offered by Atari BASIC interpreters include everything we have studied so far, plus six types of statements. We will present a brief overview of each of these additional types. You will want to

study them on your own or with a more advanced book. They are:

1. **Functions:** Functions are either *built-in* or *user-defined* expressions that operate on a given variable and perform a specific computation or action. Atari BASIC provides built-in functions (such as ABS, COS, EXP, INT, FRE, RND, SGN, SIN, SQR, and ATN). These functions will automatically perform common tasks.

Study more

Practice more

More Practice

The key to programming effectiveness is practice: write as many programs as possible, and get them to work. Develop good programming habits by following all the recommendations presented in this book. If your programs work consistently after just a few tries, you may be well on your way to becoming a disciplined and effective programmer. If they do not, watch your habits, or perhaps read parts of this book again, and then practice some more. **Remember:** there is no way you can become a good programmer unless you write many programs. This book will get you started, but it can never be a substitute for actual experience.

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Additional Techniques

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study them on your own or with a more advanced book. They are:

1. **Functions:** Functions are either *built-in* or *user-defined* expressions that operate on a given variable and perform a specific computation or action. Atari BASIC provides built-in functions (such as ABS, COS, EXP, INT, FRE, RND, SGN, SIN, SQR, and ATN). These functions will automatically perform common tasks.

Additional functions can be defined by the user. Let's examine a few of the typical built-in functions:

- The INT function computes the integer part of a decimal number by dropping the fractional part of the number. For example, INT(1.234) yields the value 1.
- Similarly, ABS computes the absolute value. For example, ABS(−5.2) is 5.2.
- The SQR function computes the square root of a number. For example, SQR(4) yields the value 2.

Functions may also be defined by the user. A user-defined function is essentially a formula written by the user that has a name, operates on a variable, and can be used in the program many times. Then every time the name of the function is used, the formula is computed with the current value of the variable.

Here is an example of a user-defined function that computes 2 percent of X:

```
10  PRINT "ENTER A NUMBER: "; : INPUT X
20  Y = X * 2 / /100
30  PRINT "2% OF YOUR NUMBER IS : "; Y
```

Let's look at these statements more closely. Line 10 asks you for a number and then assigns that number to the variable X. Line 20 creates a new variable, Y, and sets Y equal to the value of X multiplied by 2 and then divided by 100. Finally, line 30 prints the value of the variable Y. Y is called a "dummy" variable because its value is dependent on and defined by the value of X.

2. **Subroutines:** A subroutine is a group of instructions within a BASIC program that has its own name and can be used repeatedly by simply writing that name. Then every time the name of the subroutine is used in the body of the program, all the instructions within the subroutine are executed. Subroutines are convenient for executing a program segment repeatedly, without having to repeat the instructions in the program every time they are required.

Here is an example of a subroutine:

```
500  REM THIS IS SUBROUTINE AVERAGE
510  PRINT "I WILL COMPUTE THE AVERAGE OF A AND B"
520  PRINT "A =  "; A; "B =  "; B
530  AVERAGE = (A + B) / 2
540  PRINT "THE AVERAGE IS  "; AVERAGE
550  RETURN
```

Provided A and B have been assigned a value, this subroutine can be called by an instruction like:

```
50  GOSUB 500
```

It can then be used again later in the program with an instruction such as:

```
170  GOSUB 500
```

and it will yield a different value, if A and B are different. Using subroutines will clarify your program, shorten it, and save you time. You can also build a library of common subroutines and use them in various programs. However, be careful with variable names and statement numbers!

3. **String Operators:** String operators allow you to manipulate text conveniently by operating on strings of characters. Operations on strings include modifying them, measuring them, connecting them together, cutting them, inserting text to the left, the right, or at any given position, substituting characters, and comparing strings of characters. This is useful for word and text processing applications.

4. **Data Structures:** BASIC allows subscripted variables with either one or two subscripts. These variables correspond to mathematical vectors and matrices, or arrays. The use of subscripted variables allows you to set up structures like lists, and then conveniently refer to any element within the list. For example, the elements of a list named CLIENT can be referred to as: CLIENT[1], CLIENT[2], etc.; and you can print all ten values by writing:

```
50  FOR N = 1 TO 10
60  PRINT CLIENT[N]
70  NEXT N
```

You can compare two consecutive elements by writing:

```
100  IF CLIENT[K] < CLIENT[K + 1] THEN 500
```

This is a great convenience.

5. **Files:** Atari BASIC provides facilities for storing and/or retrieving data from disk files. These facilities are described in the manufacturer's documentation.

6. **Additional Resources:** Additional resources that are available with your Atari BASIC interpreter include the following statements: ON . . . GOTO, READ . . . DATA, and GO SUB . . . POP. You should explore these facilities with your Atari manual, as they will make programming easier.

In addition, there is a tabulation facility (TAB) for ease in setting up printed tables.

Finally, remember that there are interpreter-specific commands to generate graphics, produce sound effects and facilitate editing—for example, there are commands that allow you to modify your program and the files it creates—as well as aid in the running and debugging of a program. Such facilities include screen control, setting up break points at which the program will stop automatically, tracing the values of selected variables during execution, and slowing or accelerating the speed of your display.

Conclusion

The purpose of this book has been to teach you quickly and effectively how to write your first Atari BASIC programs. If you have become truly interested in BASIC, you will now want more. Your next step should be to work through all the exercises and develop some of your own programs.

As you progress, you will want to learn more advanced techniques. A list of programming books is presented at the end of this book.

I hope that you agree that learning BASIC can be easy and enjoyable, and I hope that your desire now is to do and learn more. I would appreciate hearing from you if you have any suggestions for possible improvements to this book.

Appendix A

Answers to Selected Exercises

2

2-2:

```
10 PRINT "AAAAA"
20 PRINT "BBBB"
30 PRINT "CCC"
40 PRINT "DD"
50 PRINT "E"
```

2-4: **a.** In BASIC, a label is a line number, and it must precede each statement that is part of a program.

b. The deferred execution mode is the normal mode in which a program is entered. BASIC statements are typed with line numbers, and memorized by the computer for later execution.

c. Immediate execution is the mode in which a statement is typed without a line number and executed immediately. This is also called calculator mode.

d. An empty statement is a statement that does nothing. Typically it is a line number or label that appears alone—without anything else on the same line—or with "REM."

e. A cursor is a special visual symbol on the screen (such as a square or underline) that shows your current position. It generally blinks to enhance its visibility.

f. The control or CTRL key, when pressed at the same time as an alphabetic key, will issue a specific command. Control keys make it easier to issue frequently used commands to the computer, since only two keys have to be pressed.

g. A reserved word is a name that has a specific meaning to BASIC. It may not be used as a variable by the programmer.

h. A prompt is a character or message generated by a program that indicates that the program expects the user to enter information. Atari BASIC uses the prompt ■ to mean "type your next instruction." The prompt "?" means "give me an input."

2-6: Yes, but this seems a cumbersome way to do it, since if you desire to run the program again, you must type in the statements again. Also, conditional branches (to be covered later) will not work properly when typed in this way.

2-8: Yes, BASIC will insert each statement in its proper place within the program so that all the labels are in numeric order.

2-10: No: you must type:

```
PRINT "EXAMPLE"
```

2-12: To erase statement 20 in a program, type an empty statement with the label 20.

3

3-2:

```
PRINT 1 + (½) ■ (1/(1 + (½)))
```

or

```
PRINT 1 + .5 / (1 + .5)
```

3-4:

```
PRINT 100 ■ 1.6
```

3-6:

```
PRINT 350/55
```

4

4-1:

```
10 INPUT A, B, C, D
20 SUM = A + B + C + D
30 AVG = SUM / 4
40 PROD = A * B * C * D
50 PRINT SUM, AVG, PROD
60 END
```

4-2:

```
a = no      e = yes     i = yes
b = yes     f = yes     j = no
c = no      g = no      k = yes
d = yes     h = no      l = yes
```

4-4:

```
5   DIM O$(20), F$(20), P$(10)
10  PRINT "GIVE THE NAME OF AN OBJECT";
20  INPUT O$
30  PRINT "GIVE ME THE NAME OF A PIECE OF FURNITURE";
40  INPUT F$
50  PRINT "GIVE ME THE NAME OF A FRIEND";
60  INPUT P$
70  PRINT
80  PRINT "DOES YOUR FRIEND  "; P$; "HAVE A  "; O$;
      "ON A  "; F$;  "?"
90  END
```

4-6: b, c, f are valid.

5

5-2:

```
a = yes     d = yes
b = yes     e = no
c = yes     f = no
```

5-4:

```
INPUT "YOUR NAME:  ";  NAME$
INPUT "WHAT IS 2 + 3?";  C
INPUT "THE LAST TWO NUMBERS ARE...";  A, B
```

5-6: A = 3

6

6-1: The IF statement allows the program to make decisions, thus changing its behavior according to variations in input data or computed values.

6-3:

```
a = yes     e = no
b = yes     f = yes
c = yes     g = yes
d = yes
```

6-4: Yes.

6-5: A program loop repeatedly executes a part of a program. In order to prevent an infinite loop (a loop that will not stop repeating) a test should always be made within the loop, which, when successful, allows the program to jump out of the loop.

7

7-2:

```
10  PRINT "HOURS,MINUTES  :"; : INPUT HOURS, MINUTES
20  REM VALIDATE INPUT
30  IF HOURS > = 0 AND HOURS 72 AND
      MINUTES > = 0 AND MINUTES 60 THEN 70
40  PRINT "INCORRECT, TRY AGAIN"
50  GOTO 10
60  REM PRINT LINE OF H'S
70  IF HOURS = 0 THEN 110
80  FOR A = 1 TO HOURS
90  PRINT "H";
100 NEXT A
110 PRINT
120 REM PRINT LINE OF M'S
130 IF MINUTES = 0 THEN 170
140 FOR A = 1 TO MINUTES
150 PRINT "M";
160 NEXT A
170 PRINT
180 END
```

7-4: A jump can be made into a loop not run by FOR . . . NEXT statements.

7-6:

```
10  PRINT "PROGRAM TO SUM ALL ODD INTEGERS"
20  PRINT "TO A USER-ENTERED VALUE"
30  PRINT "HIGHEST ODD INTEGER TO SUM "; : INPUT NUM
40  REM TEST FOR VALID INPUT
50  REM INT(NUM/2) < > NUM/2 CHECKS FOR ODD NUMBER -
      SEE CH. 10
60  IF NUM>0 AND NUM 10000 AND INT(NUM/2) NUM/2 THEN 90
70  PRINT "BAD NUMBER . . . TRY AGAIN"
80  GOTO 30
90  REM DO TABLE
100 PRINT "NUMBER", "SUM"
110 PRINT
120 FOR N = 1 TO NUM STEP 2
130 SUM = SUM + N
140 PRINT N, SUM
150 NEXT N
160 END
```

7-8:

```
10  PRINT "TAX RATE IN PERCENT "; : INPUT TAX
20  IF TAX <1 OR TAX >100 THEN 10
30  PRINT "PRICE", "TAX", "PRICE + TAX"
40  FOR PRICE = 1 TO 100
50  PRINT PRICE, PRICE * TAX / 100, PRICE + PRICE ■ TAX / 100
60  NEXT PRICE
70  END
```

8

8-2: Coding is one step of programming. Programming involves algorithm design, flowcharting, coding, debugging, and documenting.

8-4: A variable is traced by inserting PRINT statements to show the value of the variable at critical points in the program. Sometimes a TRACE command is provided by the interpreter to facilitate this.

8-6: A flowchart is a symbolic diagram showing the sequence of events occurring during the execution of a program.

8-8: Clearly written programs are easy to understand, and thus easy to modify. This allows the programmer who created the program, as well as other programmers, to easily change it.

Appendix B

Atari BASIC Reserved Words

This list will help you avoid using illegal names for variables.

ABS	DEG	LET	POKE	SOUND
ADR	DIM	LIST	POP	SQR
AND	DOS	LOAD	POSITION	STATUS
ASC	DRAWTO	LOCATE	PRINT	STEP
ATN	END	LOG	PTRIG	STICK
BYE	ENTER	LPRINT	PUT	STRING
CLOAD	EXP	NEW	RAD	STOP
CHR$	FOR	NEXT	READ	STR$
CLOG	FRE	NOT	REM	THEN
CLOSE	GET	NOTE	RESTORE	TO
CLR	GOSUB	ON	RETURN	TRAP
COLOR	GOTO	OPEN	RND	USR
COM	GRAPHICS	OR	RUN	VAL
CONT	IF	PADDLE	SAVE	XIO
COS	INPUT	PEEK	SETCOLOR	
CSAVE	INT	PLOT	SGN	
DATA	LEN	POINT	SIN	

Appendix C

BASIC Glossary

algorithm A sequence of steps that specify the solution to ■ given problem.

alphanumeric The set of alphabetic and numeric characters.

assignment The operation of giving ■ value to a variable, which is indicated by the " = " symbol in BASIC.

BASIC *Beginners All-Purpose Symbolic Instruction Code.* A high-level programming language designed for ease in learning.

binary A numbering system that uses only two digits: 0 and 1.

bit A contraction of the words binary digit. A bit may take the value 0 or 1.

bug Program error. Bugs should be prevented rather than cured.

byte A group of eight bits.

chip An integrated circuit that resides on ■ small silicon square mounted on a plastic or ceramic package.

coding The act of converting an algorithm or a flowchart into a sequence of program statements. This is one of the stages of the programming process.

command A reserved word used to perform ■ specific housekeeping chore, such as clearing the screen, starting a program, or accessing files. Specifying a command activates ■ specialized program inside the computer to perform the chore.

computer An enclosure containing at least a central processing unit, ■ memory, basic interfaces that allow it to communicate with the outside world, and ■ power supply. The enclosure may also include a keyboard, ■ screen, and disk drives. A computer is capable of storing programs and executing them. It communicates with the outside world by means of input/output devices. The usual input device is a keyboard. The usual output device is ■ screen and may also be ■ printer. Additional memory is usually provided in the form of disk units or cassette recorders.

CPU *Central Processing Unit.* An electronic module in charge of fetching, decoding, and executing in the proper sequence instructions stored in the memory. On most small computers, the CPU and the memory reside on a single circuit board or "card." The CPU normally uses a microprocessor chip and a few other components.

CRT *A Cathode Ray Tube.* A television-like screen.

cursor A symbol used to indicate the current position at which a character will be displayed on the screen. Often a blinking square or underline. Specialized keys are generally available to conveniently position the cursor on the screen.

data Any text or numbers on which a program can operate.

debugging Action of removing the bugs from a program. Debugging may be arduous and all efforts should be used to design a correct program so that it has as few bugs as possible.

disk Magnetic medium on which data and programs can be stored. On disk, information is organized in files that can be retrieved by name. Disks can store a large amount of data and are a common mass memory device used with small computers.

disk drive The mechanism used to read and write from a disk.

diskette A floppy disk, i.e., an 8" or 5-1/4" soft disk designed to provide inexpensive storage for programs and data.

double precision Number that has twice as many digits as in the normal representation. Each interpreter represents numbers with a set number of digits. Double precision is usually required for scientific computations or business calculations that involve large numbers or extensive computations.

editor Program designed to facilitate the entering and modifying of text. Used to remove errors or make changes while typing in a program.

empty statement A statement that does nothing. For example, the statement

```
10 REM
```

can be used to provide a space in the program and enhance readability.

endless loop A loop that has no exit point and executes forever. This is a common error made by programmers when no test condition is included in the loop or when the test always succeeds (or always fails). Breaking out of an endless loop requires the use of a special escape character—often CTRL C.

expression A combination of operands or variables separated by operators. An expression represents a formula and performs a specific calculation. When an expression is evaluated by the interpreter at execution time, it results in a value.

file A collection of information that has been given a name. A program is usually stored on a disk as a file.

fixed point number An integer, i.e., whole number, where the decimal point is in a fixed position to the right of the last digit.

floating point number A decimal number. A fixed number of digits is used internally to represent any number; and as operations are performed on the number, the position of the decimal point floats to the left or the right.

flowchart Symbolic visual representation of an algorithm.

graphics Pictures, figures, or drawings displayed on the screen, generally using a pattern of small adjacent dots. The use of color enhances the appearance of graphics.

hardware The equipment, including the computer, the disks, and any other items, that make up a computer system. *Contrast with:* software (i.e., the instruction or the programs).

high-level language A programming language designed to facilitate giving instructions to the computer. BASIC is a high-level language.

IC An *Integrated Circuit*.

initialization The phase (in a program) during which initial values are assigned to the variables. Every loop requires an initialization phase.

instruction A valid order given to the interpreter that will affect the data being operated on. Each instruction preceded by a line number is part of a program. (Commands do not affect the values of the data. They perform housekeeping chores or facilitate designing or using a program.)

integrated circuit Also called IC. An electronic circuit with many transistors and logic functions realized on a small piece of silicon.

interface Electronic circuits that allow the connection of a specific device to the computer. A disk, a printer, and a recorder require specific interfaces.

interpreter The program in charge of translating the instructions of a programming language (say BASIC) into the binary language of the computer and executing them. Once the interpreter has been installed on the computer, the computer appears to understand BASIC instructions.

I/O *Input/Output*, i.e., the communications to and from the computer.

jump Branching to, i.e., executing an instruction out of sequence.

K 1024, read as "K" or kilo. K is used to denote memory size, usually in bytes.

label A line number in BASIC.

loading Transferring data or a program into the computer's internal memory.

logical A variable or expression that takes the value true or false.

logical expression A combination of operands or variables separated by relational operators (= , > , etc.). The value of a logical expression is either true or false.

loop A sequence of program instructions that executes repeatedly until a specified event occurs, usually until a variable reaches a given value.

machine language The binary language that the computer understands directly, i.e., a limited set of instructions that manipulate binary information inside the CPU and the memory.

memory Medium that stores information. The internal memory usually resides on the same board as the CPU and stores programs and data as bytes. Mass memory units are cassettes and disks.

microcomputer A computer that uses a microprocessor as its central processing unit.

microprocessor An integrated circuit that implements most of the function of a CPU on a single chip. A contemporary microprocessor incorporates sometimes tens of thousands of transistors within a single chip and may even incorporate the memory.

monitor A minimal program required to operate a computer system. The monitor reads characters from the keyboard, displays them on the screen, and performs the basic data transfers between the keyboard, screen, and common peripherals.

MPU *Microprocessor unit*. A chip.

nested loop Loop embedded within another loop.

non-resident A program that is normally not in the permanent memory (the ROM) of the computer. A non-resident program may be stored on a cassette or diskette.

operating system A house-keeping program that provides extensive facilities for performing all common data transfers and data processing required to conveniently use the resources of a computer system. The operating system manages disk files, performs format conversions, and starts and stops programs.

operator A symbol representing any valid operation on values (i.e., + (add), * (multiply), etc.).

peripheral Device connected to a computer, such as a printer, a disk drive or a terminal.

program Sequence of instructions to be executed by the computer. Each program is written in a specific computer language and must be loaded into the computer's memory in order to be executed.

RAM *Random Access Memory*. The read/write (modifiable) portion of the computer's memory (the rest being ROM).

relational operator A logical operator that establishes a size relationship between values.

reserved word A word that has a pre-defined meaning for the BASIC interpreter. It may not be used by the programmer as a variable name.

resident A program that is stored permanently in the computer's memory, i.e., in ROM.

ROM *Read-Only Memory*. This memory may not be changed by the programmer. It generally contains part or all of the monitor and sometimes a simple BASIC interpreter.

RUN Command that starts execution of a BASIC program.

software The programs.

statement A BASIC instruction or a command, that is part of a program.

string A sequence of characters (*contrast with:* a number). In BASIC, the name of a variable is different, depending on whether it contains a string or a number. For example, WORD$ is a string variable, while NUMBER is a numeric variable.

syntax A set of rules that defines the acceptable instructions of a computer language. BASIC has a simple syntax. The interpreter always checks for, and indicates, syntax errors.

terminal Combination of a screen and a keyboard, or a printer and a keyboard, used to communicate conveniently with a computer.

variable Memory location that has a name and may take successive values over time. BASIC distinguishes between string variables and numeric variables. The name of a string variable must end with a $.

Index

Algorithm, 121–125, 128
Alphabet keys, 16
APL, 6
Arithmetic operations, 40–42
Arrow, 129
Assignment statement, 59–63
Atari BASIC, 8, 12, 24, 27, 41, 51, 53, 71, 113, 165

BASIC, 6
BASIC, versions of
  advanced, 8, 12
  Atari, 8, 12, 24, 27, 41, 51, 53, 71, 113, 165
  cartridge, 5
  extended, 7
  floating point, 7, 39
  full, 7
  integer, 7
  mini, 7–8
  tiny, 7
BASIC expression, 42
Binary, 2–3
Bit, 2
Blank, 72–73
Boldface type, 52
BREAK, 16, 19, 96
Bug, 136
Built-in function, 166
Byte, 2

CAPS/LOWR key, 17
Carriage return, 17
Cassette recorder, 10
Celsius, 45
Central processing unit (CPU), 10
Chip, 10
CLEAR, 74
COBOL, 6
Coding, 121, 151
Comma, 43
Command, 28
  END, 27, 29, 129
  FOR . . . NEXT, 109, 111, 116, 157
  GOTO, 94, 155
  IF . . . THEN, 82, 86, 89, 97
  INPUT, 50–51, 62, 72, 76, 153
  LIST, 26, 28–31, 78
  LPRINT, 22
  NEW, 28–30
  PRINT, 22, 26, 38, 43, 76, 129, 137, 153
  RUN, 23–24, 27–28, 50
  SAVE, 28
Computer, 10
CONTROL (CTRL) key, 16, 18
Control code, 18
Counter variable, 110
Counting technique, 64, 97
CPU, 10
CTRL keys, examples of, 16, 18
  CTRL A, 18
Cursor, 17, 19–20, 50

Dashes, 71
Data, 14
Data bank, 13
Data structure, 168
Debugging, 121, 136
Decision box, 129
Deferred execution, 27

Deferred instruction, 25
Deferred mode, 24
DELETE BACK S key, 16, 18, 20
Design error, 136
Diagnostic, 136, 145
Digit, 16
Direct mode, 24, 27, 138
Direct instruction, 25, 27
Disk drive, 12
Disk unit, 10
Documentation, 138–139
Documenting, 121

Empty PRINT statement, 74, 154
Empty statement, 32
END, 27, 29, 129
ENTER, 17, 21
Equal sign, 63
Erase, 18
Error, 2, 122
Error message, 22
ESC, 16, 19
Executable statement, 89
EXECUTE, 19
Execution, 27
EXIT, 19
Explicit value, 62
Exponentiation, 41
Expression, 43
Extended BASIC, 7

Fahrenheit, 45
False, 82, 87
File, 7, 168
Floating-point BASIC, 7, 39
Floating-point number, 39
Flowchart, 108, 121, 127–128, 130–131, 139, 149, 151, 155
Flowcharting, 126, 132, 144
FOR . . . NEXT, 109, 111, 116, 157
Format, 43
FORTRAN, 6
Full BASIC, 5
Function, 166
  built-in, 166
  user-defined, 166
Function key, 16, 19

Gallon, 45
GE225, 6
GOTO, 94, 155
Graphic, 169

Hand testing, 132
High-level programming language, 3–4, 6

IF, 82, 85–86, 89, 96
IF/GOTO technique, 106
IF . . . THEN, 82, 86, 89, 97
Initial value, 106
Initialization, 66, 98, 107, 110
Information, 2
Inner loop, 117
INPUT, 50–51, 62, 72, 76, 153
Input device, 9
INSERT key, 19
Instruction, 2
Integer BASIC, 7
Interactive, 6
Interface, 10, 12
Intermediate variable, 60
Interpreter, 4, 11, 112

Jump, 84, 155

K, 7
Kemeny, John, 6
Keyboard, 8–11, 14, 16
Keys, examples of
  BREAK, 16, 19, 96
  CAPS/LOWR, 17, 19
  CLEAR, 19, 74
  CTRL (control), 16, 18, 20
  DELETE BACK S, 16, 18, 20
  ENTER, 17, 21
  ESC, 16, 19, 74
  Function, 16, 19
  INSERT, 19
  RETURN, 16–17
  REVERSE VIDEO, 19
  SET-CLR-TAB, 19
  SHIFT, 16, 18, 19, 74
  SYSTEM RESET, 19, 96
Kilometer, 45
Kurtz, Thomas, 6

Label, 23
Label number, 31
Language, 2–3
Languages, high-level
  APL, 6
  BASIC, 6
  COBOL, 6
  FORTRAN, 6
  Pascal, 6
Line number, 77
Lines of stars, 113
List, 22
LIST, 26, 28–31, 78
Literal string, 58
Loading, 5, 10, 12
Logical expression, 82, 87
Logical operator, 88
Long name, 56
Loop, 95, 107, 110, 114
Looping, 114
Loops, types of
  Inner, 117
  Nested, 116, 118
  Outer, 117
Lowercase, 17
LPRINT, 22

Machine language, 2–4
Memory, 10–11
Menu, 90–91
Microprocessor, 10
Mileage, 45
mini-BASIC, 7
Modem, 13
Monitor, 11–12
Multiple statement, 71

Name, 54
Negative step, 15
Nested loop, 116, 118
NEW, 28–30
Numeric variable, 53, 58
Numerical processing, 2

Operation, 42
Operator, 40
Outer loop, 117
Output device, 12

Parentheses, 41, 62, 64
Pascal, 6
PRINT, 22, 26, 38, 43, 76, 129, 137, 153
Printer, 12
Printing numbers, 38
Program, 2–3, 14, 23
Programming, 1–2
Programming language, 3
Prompt, 21

Quotes, 43

RAM, 10–12, 27
Read-only memory, 11
Read/write memory, 10
Relational operator, 89
REM, 70, 72, 76
Renumbering lines, 140
Reserved word, 22, 55
RETURN key, 16, 17, 21, 24, 50
REVERSE VIDEO key, 19
ROM, 10–12
RUN, 23–24, 27–28, 50

SAVE, 28
Scientific notation, 39
Scientific representation, 39
Screen, 9
Semicolon, 43, 56
SET-CLR-TAB key, 19
SHIFT, 16, 19
Shortcut input, 74
Space requirements, 4
Standard, 7
Stars, 71
START, 129, 147
Statement, 3
Statements, types of
  assignment, 59–63
  empty, 32
  empty PRINT, 74, 154
  executable, 98
  INPUT, 50, 62
  multiple, 71
STOP, 19
String, 38, 55
String operator, 168
String variable, 53, 55
  dimensioning of, 56
Subroutine, 167
Sum of the first N integers, 111
Symbol, 3, 129
Syntax, 3, 13, 62, 64
Syntax error, 13, 136–137
SYSTEM RESET key, 19, 96

Tab, 43
Tables of values, 112
Testing, 136
Text, 53
Text processing, 2
Tiny BASIC, 7
Tracing, 137
True, 82, 87
Truncated, 39
Types of variable, 53

Uppercase, 18
User-defined function, 166

Validating the input, 99
Validity test, 152
Variable, 51
Variable counter technique, 65
Variable names, 52, 55, 76
  in Atari BASIC, 53–55, 76
Variable step, 114–115
Versions, 7

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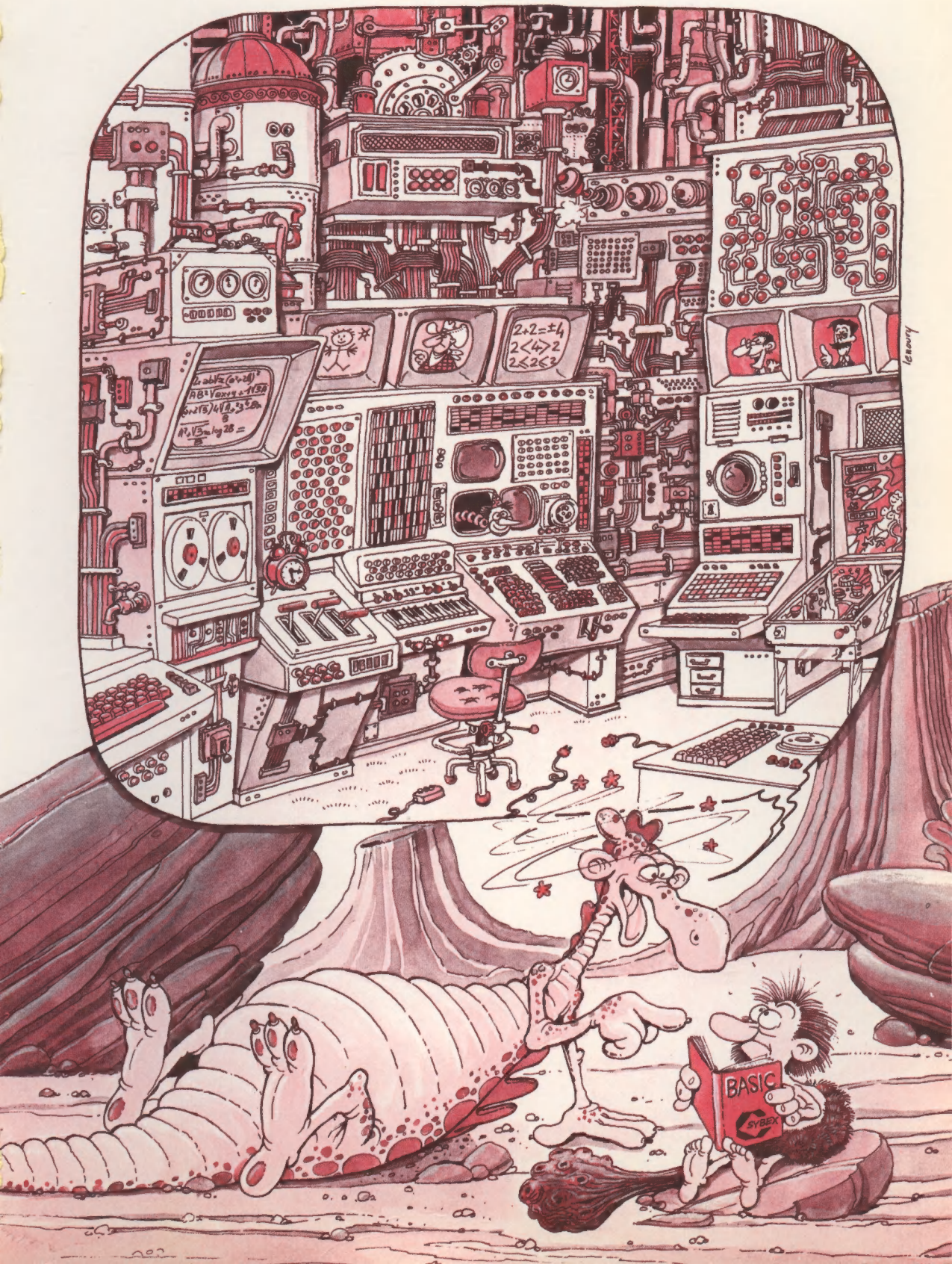

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